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informationsfusion 2009-2010

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Sammanfattning

Denna rapport är en kortfattad omvärldsanalys för området informationsfusion under hösten 2008, hela 2009 och första halvan av 2010. Syftet med rapporten är framför allt att samla uppgifter om de viktigaste forskningsartiklarna inom området och hjälpa den som vill veta mer att få en snabb överblick av det viktigaste som hänt samt ge läsanvisningar till de viktigaste publikationerna under åren.

Nyckelord: informationsfusion, omvärldsbevakning.

Summary

This report is a brief survey of information fusion research during fall 2008, all 2009 and the first half of 2010. The report is primarily intended to collect information about the most important research articles published within the research field and help readers who wish to get a quick overview of the most important developments in the field.

Keywords: Information fusion, survey report

Innehållsförteckning

1 Inledning och syfte

Denna rapport utgör en omvärldsanalys för området informationsfusion under (trots rapportens titel) hösten 2008, hela 2009 och (drygt) första halvan av 2010. Syftet med rapporten är framför allt att samla uppgifter om de viktigaste forskningsartiklarna inom området och hjälpa den som vill veta mer att få en snabb överblick av det viktigaste som hänt samt ge läsanvisningar till de viktigaste publikationerna under den angivna tiden.

Rapporten är en uppföljning till tidigare publicerade omvärldsbevaknings-rapporter från informationsfusionsprojekten på FOI[1,2,3].

Målgruppen för rapporten är dels fusionsforskare på FOI och UoH, dels tekniskt kunniga personer inom FM och FMV som är intresserade av högre nivåers fusion. För den förra gruppen är det sannolikt lämpligast att börja med att skumma igenom de utvalda artiklarnas abstract, medan den senare antagligen är mest intresserad av de referat av artiklar som gjorts. De flesta av beskrivningarna är skrivna för en läsare med god förståelse för teknik och ledningssystem. Ibland förutsätts dock även bakgrundskunskap i högnivåfusion och därmed angränsande områden såsom ontologier, textanalys, nätverks- och grafanalys, tekniker för semantisk extraktion e.t.c.

Innehållet i rapporten är avgränsat på så sätt att den inte alls tar upp verksamhet som bedrivs på FOI. Här har informationsfusionsforskning och -metodutveckling tidigare bedrivits i flera större FoT projekt; de två senaste var verksamma 2004-2006[4] samt 2007-2009[5]. Idag bedrivs det framförallt inom FoT Ledning projektet Verktyg för Informationsanalys (VIA), och inom EU-finansierade

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[1] P Hörling, C Mårtenson, J Schubert, R Suzic och P Svenson. A survey of some Information Fusion research fields applicable in Operations Other Than War. 2006. Se http://www.foi.se/infofusion/bilder/FOI-R--2000--SE.pdf

[2] P Berggren, P Hörling, C Mårtenson, J Schubert, R Suzic och P Svenson. Viktig informationsfusionsforskning i omvärlden under 2006. 2007. Se http://www.foi.se/upload/projects/fusion/FOI-R--2252--SE.pdf

[3] P Svenson. Omvärldsanalys Informationsfusion 2007 – 2008. 2008. Se http://www.foi.se/upload/projects/fusion/FOI-R--2536--SE.pdf

[4] P Hörling, K Johansson, B Kylesten, C Mårtenson, J Schubert, R Suzic och P Svenson. Slutrapport från FoT-projekt Teknik, Metodik och Demonstrationssystem för Informationsfusion (TMDI). 2006. Se http://www.foi.se/upload/projects/fusion/FOI-R--2164--SE.pdf

[5] P Svenson, P Berggren, J Brynielsson, L Ferrara, R Forsgren, G Holm, A Horndahl, P Hörling, L Kaati, B Kylesten, M Lundin, C Mårtenson, J Schubert, E Sjöberg, P Svan, P Svensson, E Tjörnhammar och J Walter. Slutrapport från FoT-projekt Situations- och Hotanalys för Battlegroup 2011. 2009. Se http://www.foi.se/upload/projects/fusion/FOI-R--2859--SE.pdf

projekt som Support. FOI utför även tillämpad informationsfusionsforskning i FoT-transferprogramsprojektet Impactorium. För en sammanfattning av dessa verksamheter hänvisas till årsrapporter för respektive FoT-områden. Rapporten tar knappt heller upp lågnivåfusion (fusionsnivåerna 0 och 1) såsom signal-behandling, målföljning, målassociation, målidentifiering, bildfusion e.t.c.

Rapporten består av 14 kapitel. Kapitel 2 beskriver kort utvecklingen inom informationsfusionsforskningen i allmänhet under den aktuella perioden, medan kapitel 3 till 11 ger korta beskrivningar av några forsknings, eller "temaområden" som bedömts särskilt intressanta. För varje område lyfts några få särskilt intressanta artiklar fram. Vi har försökt välja artiklar som inte bara går på djupet i någon enskild forskningsdetalj, utan är bredare och mer lättlästa för en större läsekrets. Det skall noteras att temaområden är svåra att välja ut eftersom många av artiklarna spänner över flera områden, varför ett fick väljas att placera artikeln i. I synnerhet gäller detta kapitlen för ontologier, semantiska nät och textanalys där tekniker från alla tre områdena ofta används i sammanhängande system för situations- och hotanalys som även det är ett enskilt kapitel. Samtliga artiklar som sammanfattats refereras till i form av fotnötter med kortfattad publiceringsinformation. De återfinns dessutom i kapitel 12, 13 och 14 som innehåller omfattande listor med intressanta artiklar som publicerats under de två åren, åtskilliga fler än de som sammanfattats i rapporten. För varje artikel listas i dessa kapitel publiceringsinformation och abstract. Två områden som är intressanta för informationsfusion, men där inga artiklar hunnit sammanfattas p.g.a. tidsbrist är visualiseringsmetoder för att underlätta analys och fusion av stora mängder heterogen information (eng. visual analytics), samt s.k. Finite Set Statistics (FISST). Dock har ett antal artiklar inom dessa bägge områden tagits med bland de utvalda abstracten. Området visual analytics kommer att beröras i en planerad publikation under 2011.

Urvalet av artiklar som tagits med i sammanställningen har framförallt gjorts utifrån en utgångspunkt: Vad som är intressant och viktigt för svenska förhållanden, det vill säga för de operationsmiljöer och ledningsnivåer inom vilka Försvarsmakten verkar idag. En del artiklar som bedömts mindre tillämpningsnära men av stort forskningsintresse har också tagits med. De främsta konferenskällorna som genomsökts är det internationella fusions-forskningssamfundets International Society of Information Fusion (ISIF) årliga konferens (International Conference on Information Fusion), SPIE:s Defense and Security-konferenser, International Command and Control Research and Technology Symposium (ICCRTS) 2010, ett par NATO RTO symposier, ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD) samt symposier för ontologier inom underrättelsevärlden (OIC och STIDS). På tidskriftssidan har tidskrifterna Information Fusion, Journal of Advances in Information Fusion, Journal of Decision Support Systems, samt International Journal of Approximate Reasoning genomsökts. För dessa källor har samtliga under de två åren publicerade artiklar granskats för att avgöra om de är

intressanta nog att tas med. Dessutom har vi låtit göra breda sökningar i litteraturdatabaser med lämpliga termer för att hitta andra intressanta artiklar, för de söksträngar som använts se Appendix 1. De flesta träffarna hamnade på artiklar som redan hittats i de ovan angivna källorna, i övrigt var resultatet magert. Det bör nämnas att ett stort antal för forskningsområdet intressanta artiklar publiceras vid olika andra data mining-konferenser. Inga av dessa har dock bedömts vara tillräckligt tillämpningsnära för att inkluderas här, antingen eftersom de är alltför teoretiska eller eftersom tillämpningarna skiljer sig för mycket från militärt relevanta. För en fusionsforskare som är intresserad av algoritmutveckling är dock hela området data mining synnerligen intressant att följa. Detsamma gäller också för andra angränsande områden, till exempel konferenserna IPMU (Information Processing and Management of Uncertainty in Knowledge-based Systems), UAI (Uncertainty in Artificial Intelligence) och ICML (International Conference on Machine Learning).

2 Kort om den allmänna utvecklingen

Den öppet publicerade utvecklingen inom området berör fortfarande i stor utsträckning de lägre JDL-nivåerna[6] inom fusionen; nivå 0 och 1: Signalbehandling och multisensorfusion, huvudsakligen ämnat för målföljning och målidentifiering, bildfusion, navigering etc. Mängden publikationer kring området informationshantering (resursallokering, distribuerad fusion) i sensornätverk, även mycket stora sådana, ökar kontinuerligt.

Mängden publikationer inom de högre nivåernas fusion, 2 och 3 (situations- resp hot- eller konsekvensbedömning) ökar också, men verkar ha bromsat upp något. En grupp sessioner som de senare åren förekommit på "Information Fusion", den årliga konferensen inom området, är hur man sambearbetar information från såväl sensorer som människor; de förra uttrycker sig huvudsakligen på ett sätt som en dator lättare kan bearbeta, d.v.s. kvantitativt numeriskt i en eller flera dimensioner, medan de senare uttrycker sig mer kvalitativt; huvudsakligen i liknelser, bilder och, framför allt, i textform. Bägge kan leverera information till fusionsnivåerna 1 och uppåt, men svårigheten ligger i att sambearbeta "hård" sensor och "mjuk" mänsklig information som helt eller delvis beskriver en viss situation eller händelse som observerats. Ett kapitel i denna rapport berör detta.

I och med detta blir det även vanligare att studera hur människan bättre skall kunna bli en del av informationshanteringsloopen, inte bara som informations-givare tillsammans med tekniska sensorer, utan som analytiker och fusionerande aktör, tillsammans med datorn. Arbetssättet att låta datorn göra de den är bäst på (viss mönsterigenkänning, sökning och bearbetning av stora mängder likformig information), och människan det den är bäst på (abstrakt resonerande och slutsatsdragande från mer heterogen information) och gemensamt resonera sig fram till ett resultat brukar på engelska benämnas "mixed-initiative reasoning", och några här refererade artiklar tar upp detta.

Ett stort problem sedan länge är att det är svårt att hitta relevanta testdata för att utvärdera högnivåfusion, i synnerhet om det skall kombineras med lägre nivåers sensorfusion. Försök har gjorts att generera sådana testdata utifrån simulerade scenarier med alltifrån videoströmmar till mänskligt genererade textmeddelanden och frivilligt inlagd information om händelseförloppet från olika sociala nätverk på Internet där snabb uppdatering brukar ske, exempelvis Twitter.

Sensorer är ofta kalibrerade för att kunna leverera data med viss uppskattad osäkerhet, något som är lätt att beskriva numeriskt med en standardavvikelse eller liknande. Människor har en mycket bredare repertoar för att beskriva en

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[6] För JDL-nivåerna, se exempelvis Handbook of multisensor data fusion; theory and practice, 2d ed. Ed. by Martin E. Liggins et al, CRC / Taylor & Francis, 2009 samt D A Lambert. A blueprint for higher-level fusion systems. Information Fusion Vol. 10, Nr. 1, Januari 2009, s. 6-24.

observerad situation och med vilken osäkerhet denna uppfattats. Spridningen vad begreppet "osäkerhet" här kan betyda är då stor, och det är något som börjat adresseras allt oftare i olika artiklar. Ofta gäller det s.k. ontologisk osäkerhet som hanterar kvalitativ osäkerhet i *vad* som beskrivs bättre än kvantitativa osäkerheter i *hur stort* något är, såsom avstånd till och fart hos ett mål som mätts in med en radar, eller koncentration av en viss förorening i luften. När olika organisationer skall samarbeta och utbyta information är det vidare viktigt att den förstås på ett konsistent sätt av alla inblandade, d.v.s. att man uppnått semantisk interoper- abilitet. Detta innebär att olika informationsobjekt baserade på olika ontologier måste kunna utbytas korrekt, något som blivit ett allt hetare område inom FoU..

Ett mycket intressant område som dykt upp de senaste åren är att utifrån inkommen information om en händelseutveckling undan för undan bygga ett semantiskt nätverk som beskriver situationen och dess historia med fysiska aktörer, organisationer, platser, infrastruktur m.m. och deras relationer. Sedan kan man söka efter intressanta "delsituationer" genom att använda grafteoretiska metoder på det semantiska nätverket (som är en s.k. attribuerad graf) för att känna igen en mall i form av en delgraf som beskriver den sökta delsituationen. Det går att kräva exakt matchning mellan hittade delsituationer och mallen (isomorfi) eller mer eller mindre exakt match inom ett visst variationsintervall (homeomorfi). Metodiken kan sägas vara såväl kvantitativ som kvalitativ. Det är framför allt James Llinas forskningsgrupp vid State University of New York i Buffalo som är verksamma inom området. Avsikten är att man skall låta domänexperter (eng. Subject Matter Experts eller SMEs) beskriva intressanta hypotetiska delsituationer de letar efter i form av subgrafer som man då och då testar närvaron av i det semantiska nätverket som undan för undan växer då ny information kommer in. Åtskilliga artiklar från denna forskningsgrupp refereras i denna rapport.

En annan viktig aktör inom området situationsmodellering är Mitch Kokars forskningsgrupp vid Northeastern University och Vistology Inc. Här har man specialiserat sig på att utveckla ontologier för situationsbeskrivning samt att använda dessa i olika mjukvaruverktyg för att beskriva situationer och deras temporala utveckling, alltifrån militära situationer till situationer i utrycknings- och katastrofscenarier.

Starkt påminnande om uppbyggnad och analys av semantiska nätverk är social nätverksanalys (SNA) som är ett område som skapar allt mer intresse, och som överlappar med informationsfusion. Det har länge funnits inom exempelvis sociologi och kriminalunderrättelsetjänst, men har de senaste åren blivit allt viktigare för underrättelsetjänsten vid olika internationella konflikthärdar såsom Afghanistan för att bena ut de strukturer som finns inom olika stridande fraktioner och grupperingar, och deras kopplingar till mer eller mindre löst sammanhängande kriminella nätverk.

Att kunna upptäcka avvikelser från normalläget är viktigt vid all form av övervakning, det kan handla om allt från vibrationer i en maskin eller vattenflöden i avloppsnät till (och mera relevant här) rörelser i folkmassor, stämningslägen på bloggar, rörelsemönster hos fartyg på havet, nätverks-kommunikation m.m. Först måste ett normalläge beskrivas vilket kräver någon form av erfarenhet om vad ett sådant är, en erfarenhet som ju kontinuerligt ökar ju längre övervakningen pågår. Situationen övervakas och jämförs kontinuerligt med detta normalläge. När någon form av gränsnivå överskrids, oftast med hänsyn tagen till ett ständigt närvarande "bakgrundsbrus", skall systemet alarmera. En del bidrag som anknyter till just anomali- eller avvikelsedetektion kommer att refereras.

Tjänstegränsytor i stora nätverk för förenklad plug-and-play hantering av sensorer, fusionsmoduler och anslutning mot ledningsplatser är ett annat intressant område, som dock ligger på gränsen till vad denna rapport avses handla om. Några bidrag inom detta område refereras dock närmare, tillsammans med några artiklar som berör system för uppbyggnad av gemensam läges-förståelse.

3 Situations- och hotbedömning

Detta är det som enligt JDL-modellen brukar motsvara fusionsnivå 2 och 3. I nivå 2 skapar man sig en uppfattning om relationerna mellan de objekt man urskiljt i nivå 1, samt sätter in det hela i en gemensam kontext för att skapa uppfattning om situationen. I nivå 3 prognosticerar man den bedömda situationen från nivå 2 framåt för att bedöma vad den kan ge för konsekvenser i framtiden, civilt kan man kanske snarare kalla det *konsekvensbedömning* eller för utfall man vill undvika: *riskbedömning*. Hotbedömning, eller hotanalys, är ett mera militärt synsätt. Området är ganska "spretigt" till sin karaktär; de bägge fusonsnivåerna hänger mycket starkt samman och överlappar med flera av de senare kapitlen, men ett antal artiklar som bedöms vara representativa här sammanfattas nedan.

Rein[7,8] et al beskriver ett tänkt verktyg för att i nära realtid utföra en ytlig men snabb genomsökning av inkommande information för att möjliggöra snabb uppflaggning av potentiella hotsituationer. I ett första steg sker konvertering av den inkommande informationen till det standardiserade formatet Battle Management Language (BML), detta eftersom information insamlad från olika källor ofta kommer i olika format. I nästa steg söks informationen igenom för att finna så kallade triggers för att koppla inkommande information till eventuella hot. Som ett exempel kan införskaffandet av gödningsmedel överensstämma med hotet att någon förbereder en bombattack.

Beaver[9] et al föreslår i ett relaterat papper ett generellt ramverk för hot-bedömning, tänkt att kunna användas för att stödja operatörer med att identifiera hot och besluta om lämpliga åtgärder. Potentiella hot bryts ner i så kallade hotsignaturer, vilket är attribut eller egenskaper hos hotet som är detekterbara. Dessa hotsignaturer kan likställas med de triggers som används av Rein et al. Vid själva hotbedömningen används Bayesianska nätverk, vilka utför probabilistiska beräkningar för att bedöma graden av hot.

Irandoust[10] et al beskriver hantering av igenkänning av lufthot inom marinen. Författarna presenterar sitt system Threat Evaluation Support System (TESS) som syftar till att motverka operatörernas kognitiva stress. Systemet tillhanda-

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[7] K Rein och U Schade. How certain is certain? Evaluation of uncertainty in the fusion of information derived from diverse sources. Fusion 2009.

[8] K Rein, M Frey, U Schade och S Kawaletz. ALARM for early warning: a lightweight analysis for recognition of menace. Fusion 2010.

[9] J Beaver, R Kerekes och J Treadwell. An information fusion framework for threat assessment. Fusion 2009.

[10] H Irandoust, A Benaskeur och F Kabanza. A mixed-initiative advisory system for threat evaluation. ICCRTS 2010.

håller både proaktiv och reaktiv information, d.v.s. det försöker förutse vilken slags information operatören kommer att behöva, samt ger operatören information som reaktion på vad operatören beslutar. Systemet parametriserar hotbilden genom att dela upp den i olika sorters indikatorer, t.ex. förmåga, tillfälle och avsikt. Systemet tillhandahåller även interaktionsmöjligheter som tillåter operatören att få en textuell bild av hur ett beslutsunderlag har räknats fram. I övrigt är TESS-gränssnittet av grafisk karaktär. En tidigare version av systemet testades av kanadensiska marinen som gav det ett bra betyg.

Hotbedömning är inte bara intressant i militära tillämpningar utan är också av stort intresse för bland annat intrångsdetektion i nätverk. Informationsfusion inom IT-säkerhetsområdet är ett nytt område där inte mycket gjorts, åtminstone inte under titeln "Informationsfusion", men för varje år blir mängden bidrag i informationsfusionslitteraturen större. Si[11] et al diskuterar ett ramverk för hotbedömning i nätverk, där attributigenkänning (eng. attribute recognition) används. Arbetet tycks än så länge vara relativt outvecklat, men visar på civila områden med samma typ av problem som mer traditionellt återfinns i den militära domänen. Ett annat välkommet tillskott kommer från Yang et al[12] där metoder från informationsfusionsområdet används att korrelera och fusionera information från nätverksövervakning. Man följer de olika stegen, s.k. "attack tracking", i ett pågående intrångsförsök i realtid och försöker hitta intrångs-mönster bl.a. med hjälp av redan kända mönster. Man progonosticerar utifrån detta de möjliga mål (hotbedömning) som ett intrångsförsök kan ha. Man konstaterar dock att mycket arbete finns kvar att göra inom området.

Costa[13] et al från George Mason University presenterar PROGNOS, vilket är ett system för prediktiv situationsuppfattning för användning i den maritima domänen. Verktyget är avsett som stöd för mänskliga operatörer som i ett större scenario försöker identifiera aktörer som beter sig misstänkt och kan utgöra någon form av hot. Systemet skall kunna hantera information från flera olika heterogena sensorer och system, vilket ställer höga krav på interoperabilitet och konsistent hantering av osäkerhet. För att stödja detta används PR-OWL, vilket är baserat på Bayesiansk första ordningens logik. I en senare artikel av Carvalho

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[11] J Si, Q Zhang, D Man, K Wang och W Yang. Network Threat Assessment Based on Attribute Recognition. Int Conf. on Advanced Communication Technology, 2009.

[12] S J Yang, A Stotz, J Holsopple, M Sudit och M Kuhl. High level information fusion for tracking and projection of multistage cyber attacks. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s. 107-121.

[13] P C Costa, K-C Chang, K Laskey och R Carvalho. A multi-disciplinary approach to high level fusion in predictive situational awareness. Fusion 2009.

et al[14] ligger fokus på de senaste vidareutvecklingarna i systemets "reasoning"-modul samt i simuleringsmodulen. I reasoning-modulen (som är baserad på Bayesianska nät, BN) har man implementerat tre olika approximativa inferensalgoritmer. Vidare har man försökt minska komplexiteten i beräkningarna genom att utveckla och implementera en metod för att bryta ner BN i sektioner, s.k.Multi Entity Bayesian Network fragments (MFrags). Man har också empiriskt undersökt skalbarheten i den algoritm som bygger upp de BN som används vid inferensen.

Dahlbom och Niklasson[15] behandlar problemet med situationsigenkänning, dvs. att hitta situationer bestående av a priori definierade temporala mönster i inflöden av information. Ett exempel som ges är igenkänning av situationer där ficktjuvar stjäl plånboken från sina offer och lämnar över denna till en medbrottsling. För att kunna identifiera denna typ av situationer används så kallade Petri nets, vilka kan skapas manuellt av en expert, eller läras in automatiskt utifrån data, med hjälp av exempelvis genetiska algoritmer.

Situationer är även centrala i ett arbete presenterat av VIStology, Inc., där fokus ligger på att modellera situationer och situationsbeteenden[16]. För att kunna göra detta har de skapat en så kallad Situation Theory Ontology (STO), baserat på arbete av Devlin samt Barwise och Perry. Kokar[17] et al visar i "Situation Tracking: The Concept and a Scenario" hur denna framtagna ontologi kan användas rent praktiskt i ett relativt enkelt men konkret scenario.

Intentions- eller planigenkänning är ett problem som är av intresse för en mängd olika tillämpningar. Exempel på sådana tillämpningar är bekämpning av datorintrång, upptäckt av organiserad brottslighet, samt att resonera om fiendens taktik i militära scenarion. Kort sagt består problemet av att detektera utförandet av en plan innan dess sluttillstånd är nått. Igenkännandet av planer baseras på observerade handlingar, där observationerna ofta är associerade med osäkerhet. Krauthausen och Hanebeck[18] föreslår användandet av så kallade dynamiska

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[14] R. Carvalho, P. Kosta, K. Laskey och K. C. Chang. PROGNOS: predictive situational awareness with probabilistic ontologies. Fusion 2010.

[15] A Dahlbom och L Niklasson. Evolving Petri Net Situation Templates for Situation Recognition. SWIFT 2009.

[16] C J Matheus et al. Situational Behavior Modeling. VIStology, Inc. Internal Report, Contract Number FA9550-06-C-0025, June 30, 2009.

[17] M M Kokar, J J Letkowski, R Dionne och C J Matheus. Situation Tracking: The Concept and a Scenario. IEEE Military Communications Conference (MILCOM 2008).

[18] P Krauthausen och U Hanebeck. Intention recognition for partial-order plans using Dynamic Bayesian Networks. Fusion 2009.

Bayesianska nätverk för probabilistisk planigenkänning, medan Matthews[19] et al från BAE Systems använder sig av Monte Carlo-filtrering för att uppskatta sannolikheten för att en viss plan är under utförande.

Under senare år har ett stort antal algoritmer och prototypsystem för högnivåfusion tagits fram, men det är ännu relativt sällsynt med systematiska utvärderingar eller jämförelser av dessa. Algoritmer och system för lågnivåfusion är relativt lätta att utvärdera kvantitativt eftersom det där finns standardmetriker och "benchmarking" för utvärdering, men detsamma gäller inte för högnivå-fusion. Blasch, Valin och Bossé[20] tar upp så kallade Measures of Effectiveness (MOEs) för högnivåfusionssystem och visar på behovet av mer arbete för att möjliggöra systematiska utvärderingar även av algoritmer och system inom detta område.

Ett stort problem sedan länge, och starkt relaterat till det närmast ovan nämnda, är att det är svårt att hitta relevanta testdata för att utvärdera högnivåfusion, i synnerhet om det skall kombineras med lägre nivåers sensorfusion. I en artikel av Hall[21] et al beskrivs "extreme events laboratory", där man utvecklar en miljö för skapande av testdata och utvärdering av fusionssystem med människan i centrum. Försök har gjorts att generera sådana testdata utifrån simulerade scenarier med alltifrån videoströmmar till mänskligt genererade textmeddelanden och frivilligt inlagd information om händelseförloppet från exempelvis Twitter.

Utvärdering av högnivåfusionsalgoritmer är även i fokus för Valin[22] et al, vilka presenterar CanCoastWatch. Detta är en testbädd som låter forskare testa förmågan hos algoritmer för dynamisk resurshantering och distribuerad datafusion i en relativt realistisk miljö för kustövervakning.

Anderson och Hong[23] beskriver hur hotbedömningen i ett Integrated Air Defense Systems (IADS) kan kopplas till sensorerna för att möjliggöra målbaserad sensorstyrning. Ett IADS består, utöver eldenheter, bland annat av luftförsvarsradarer och andra typer av sensorer, och används i syfte att hindra motståndaren från att bekämpa markbaserade skyddsobjekt. För att åstadkomma

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[19] G Mathews, D Nicholson, A McCabe och M Williams. Plan detection under partially observable and cluttered conditions. Fusion 2010.

[20] E Blasch, P Valin och E Bossé. Measures of effectiveness for high-level fusion. Fusion 2010.

[21] D Hall, J Graham, L More och J Rimland. Test and evaluation of soft/hard information fusion systems: a test environment, methodology and initial data sets. Fusion 2010.

[22] P Valin, E Bossé, A Guitouni, H When och J Happe. Testbed for distributed high-level information fusion and dynamic resource management. Fusion 2010.

[23] J Anderson och L Hong. Sensor Resource Management driven by threat projection and priorities. Information Sciences, Volume 178, Issue 8, 15 April 2008, p. 2007-2021.

detta krävs en god målföljning, framförallt av de mål som av hotbedömningen ges hög prioritet. För hotutvärderingen används PASC, vilket står för Probabilistic Accumulative Situation Calculus. Pappret är intressant genom att det i ett konkret system knyter ihop alla fusionsnivåer, från målföljning till situations- och hotanalys, samt resursstyrning.

Hotutvärdering och resursallokering är även centralt för Couture och Menard[24], vilka presenterar en del av Lockheed Martin Canadas forskning rörande STA/RM, d.v.s. Situation and Threat Assessment and Resource Management. I deras arbete bedöms graden av hot som ett mål utgör mot ett skyddsobjekt baserat på den möjlighet, förmåga och intention som målet bedöms ha att skada eller förstöra skyddsobjektet.

I en SPIE-artikel av Antony och Karakowski[25] diskuteras likhets- och olikhets-begreppet, liksom närhetsbegreppet som alla är fundamentala för fusion. Dimensionerna tid och rum är enklast att hantera i kraft av sin numeriska karaktär och kontinuitet. Kvalitativa "dimensioner" som identitet, färg, form, beteende (kallas entiteter) e.t.c. är mer diskreta och svårjämförbara och åtskilliga mer eller mindre väsensskilda typer av algoritmer kan komma i fråga för att göra jämförelsen mellan rapporter om två objekt (eller händelser, tillstånd); är de samma, lika eller olika? Genom att studera likheten i de olika kvantitativa och kvalitativa dimensionerna kan man tala om den totala graden av likhet mellan två objekt. Detta görs i denna artikel genom att jämföra komponenterna i s.k. fusionstriplar *<entitet, plats, tid>* såväl som mellan olika entitetsklasser. Exempel ges från underrättelsetjänst, kollisionsundvikande inom luftfart samt fusion av sensorinformation inom robotik.

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[24] J Couture och E Menard. Issues with Developing Situation and Threat Assessment Capabilities. Harbour Protection Through Data Fusion Technologies. NATO Science for Peace and Security Series C: Environmental Security, 2009, p. 171-179.

[25] R T Antony och J A Karakowski.. First-principles mapping of fusion applications into the JDL model. Proc. SPIE, Vol. 7336, 73360J (2009).

4 Hard / Soft Fusion

Under de senare åren har allt mer arbete inriktats åt att försöka knyta samman fusion av sensordata (hard, "hård") med fusion av mänskligt genererad information (soft, "mjuk"). Området betraktas som svårt eftersom det handlar om att gifta samman kvantitativa och kvalitativa metoder, och diverse angreppssätt har framförts. Inte bara handlar det om svårigheten att jämföra objekt, händelser eller tillstånd som beskrivs på helt olika sätt, utan också att kunna jämföra osäkerhetsuppskattningar som även de ofta är väsensskilda.

Ett par arbeten[26,27] beskriver ett SOA[28]-baserat system som håller på att utvecklas för den brittiska civila räddningstjänsten. Det skall erbjuda informationsutbyte, situationsbedömning och beslutstöd. Systemet är ämnat att fusionera analyserad sensorinformation med mänskliga observationer, det beskrivs på generell nivå och skall kunna hantera alla fusionsnivåer. Artiklarna innehåller för övrigt en läsvärd genomgång av de problem man ställs inför generellt vid fusionering av sensor- och mänskligt genererad information, såsom de olika typer av osäkerhet man då måste hantera. Ontologiska osäkerheter beskrivs exempelvis med PR-OWL, utvidgningen av ontologibeskrivnings-språket OWL med det här tidigare omnämnda Multi Entity Bayesian Networks (MEBN) och Description Logic.

En publikation av mer psykologisk karaktär kommer från Jones, Connors och Endsley[29]. Metodiken Goal-Directed Task Analysis (GDTA) för att formellt beskriva en användares eller rolls mål, behov och krav på situationsuppfattning används här för att modellera den mänsklige användarens behov och förmåga att samspela med ett fusionssystem. Fuzzy logik, speciellt i form av s.k. Fuzzy Cognitive Maps, används. I dessa beskrivs det "mentala landskapet" av aktiviteter, mål och delmål en aktör tänker och har sitt mentala fokus på, och i vilken utsträckning de påverkar varandra kausalt. En aktör kan ha flera (del)mål i sikte som konkurrerar om hans / hennes kognitiva förmåga vilket kan beskrivas med metoden.

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[26] D Stampouli och D Vincen. Situation assessment for a centralised intelligence fusion framework for emergency services. Fusion 2009.

[27] D Vincen, D Stampouli och G Powell. Foundations for system implementation for a centralised intelligence fusion framework for emergency services. Fusion 2009.

[28] SOA – Service Oriented Architecture; Tjänstebaserad Arkitektur.

[29] R Jones, E Connors och M Endsley. Incorporating the human analyst into the data fusion process by modeling situation awareness using fuzzy cognitive maps. Fusion 2009.

Ett annat bidrag för den psykologiskt intresserade läsaren är ett av Blasch[30] et al om hur kunskap om kulturell bakgrund hos en motståndare kan användas för att justera förmågan hos ett informationsfusionssystem. Kunskapen kan i princip ackumuleras genom användning av Bayes' regel. Kulturell bakgrund inverkar även den på hur användare interagerar med fusionssystemet och påverkar dess funktion.

Ett bidrag som diskuterar mixed-initiative (MI) reasoning kommer från Belov och Gerken[31]. Det konstateras att full automatisering av soft / hard fusion är svårt eller omöjligt, och att en mixed-initiative lösning är bäst där datorn hanterar en del automatiserade funktioner och människan drar slutsatser på högre abstraktionsnivå och utför (i samverkan med datorn) association och fusionering av heterogen information. Ett system beskrivs där två automatiserade funktioner (ett underrättelserapporthanteringssystem och ett system för att från rapporterna bygga upp sociala nätverk) kopplas samman med hjälp av en MI funktion. Användaren kan inverka och ge förslag då systemet försöker att uppdatera det sociala nätverket med ny inkommen information, och eventuellt fusionera den med redan existerande strukturer i nätverket. Det hela exemplifieras med ett scenario.

Dempster-Shafer (DS) metodik används av Premaratne[32] et al för att associera tidsstämplade (hard) sensorobservationer, med likaså tidsstämplade (soft) mänskliga observationer för att se om de bägge kategorierna av information sannolikt kan relateras till samma händelseutveckling utifrån de tidpunkter och tidsintervall under vilka observationerna gjordes. Kvalitativ information såsom trolig identitet eller typklass hos ett observerat objekt kan även ingå i samman-vägningen. Bidraget går in ganska detaljerat på DS teori, men är ett intressant exempel på hur DS kan användas för att underlätta hard / soft fusion.

I ett allmänt hållet papper av Nagi[33] et al beskrivs forskningen vid University of Buffalo kring olika metoder för att vidareutveckla området hard / soft fusion. En viktig fråga som nämns är exempelvis på vilken abstraktions/fusionnivå det är lämpligast att göra fusion beroende på typen av källinformation. En annan fråga är den allestädes närvarande om "alignment" eller hur man skall göra heterogen

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[30] E Blasch, P Valin, E Bossé, M Nilsson, J van Laere och E Shahbazian. Implication of culture: User roles in information fusion for enhanced situational understanding. Fusion 2009.

[31] N Belov och P Gerken. Mixed initiative soft data fusion associate. Fusion 2009.

[32] K Premaratne, M Murthi, J Zhang, M Scheutz och P Bauer. A Dempster-Shafer theoretic conditional approach to evidence updating for fusion of hard and soft data. Fusion 2009.

[33] R Nagi, J Llinas, D Hall och J Lavery. A multi-disciplinary university research initiative in hard and soft information fusion: overview, research strategies and initial results. Fusion 2010.

information om samma skeende "jämförbar" så fusion alls kan genomföras, exempelvis hur olika osäkerhetsbeskrivningar skall kunna jämföras.

Grafiska modeller såsom Bayesianska nätverk har under de senaste tjugo åren blivit populära verktyg för att resonera under osäkerhet. Influensdiagram är en typ av grafisk modell som har grunden gemensam med Bayesianska nätverk, men som också tillåter nytto- och beslutsnoder. Detta möjliggör att inte bara kunna resonera under osäkerhet, utan också fatta beslut under osäkerhet, baserat på principen om maximerad förväntad nytta. Bielza[34] et al belyser några av problemen och svårigheterna med att utvinna grafiska modeller från mänskliga domänexperter, SMEs, samt presenterar metoder för att övervinna några av svårigheterna. Ett protokoll för hur intervjuer med domänexperter kan utföras för att undvika vanliga fallgropar presenteras, vilket kan vara till nytta för projekt där arbete med att utvinna denna typ av modeller utförs.

Slutligen nämns här ett bidrag om informationskvalitet som av Rogova och Bossé[35]. Detta är ett användarorienterat begrepp som handlar om att informationen inte bara skall ha låg osäkerhet, den skall även bl.a. vara relevant i sammanhanget och vara användbar för den som efterfrågar den. Åtskilliga fler aspekter på informationskvalitet behandlas på en resonerande nivå, och man föreslår ontologier eller taxonomier för hur de olika aspekterna relaterar till varandra. Bidraget är intressant genom att det ger en insikt i hur komplext informationskvalitetetsbegreppet är på olika abstraktionsnivåer, och hur viktigt det är att man tar hänsyn till det för framgångsrik fusion.

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[34] C Bielza, M Gómez, and P P Shenoy. Modeling challenges with influence diagrams: Constructing probability and utility models. Decision Support Systems, Vol. 49, Nr. 4, November 2010, s. 354-364.

[35] G Rogova och E Bossé. Information Quality in Information Fusion. Fusion 2010.

5 Ontologistödd fusion, Semantic Web

Att med hjälp av speciella beskrivningsspråk begripliga för datorer beskriva kunskap om taxomomier och relationer i form av ontologier är ett viktigt sätt för att få de annars kvantitativt arbetande datorerna att även kunna hantera kvalitativ information och semantik. Området relaterar starkt till de tidigare kapitlen om nivå 2 samt hard / soft fusion och med semantiska nätverk men har fått ett eget kapitel.

Att upprätthålla säkerheten på flygplatser utan att påverka resenärerna alltför negativt är ett svårt problem. Potentiella hot spänner från knarksmuggling till terroristattacker och den teknologiska utmaningen i att kunna ge säkerhets-personalen en bättre situationsuppfattning är stor. Fenza[36] et al har använt sig av Mitch Kokars generiska Situation theory Ontology (STO, jmf sid 15) genom att kombinera denna med en specifik domänontologi för situationer relaterade till flygplatssäkerhet. Resultatet är dock långt ifrån något färdigt system, utan pekar snarare på en potentiell logikbaserad väg framåt.

Inyaem[37] et al arbetar med ett ramverk för att automatiskt kunna extrahera händelser med hjälp av så kallad fuzzy ontology learning (ung. luddig ontologi-inlärning). En fuzzy ontologi bygger på användandet av fuzzy sets, där en medlemskapsgrad i intervallet [0,1] tilldelas varje relation mellan de ingående objekten i ontologin, baserat på hur stark relationen mellan objekten är. Deras förhoppning är att ramverket skall kunna användas i samband med terroristbekämpning.

Little och Rogova[38] behandlar problemet att designa ontologier för högnivåfusion. Författarna föreslår en process för att metodiskt bygga upp en ontologi där man tydligt skiljer mellan "spatiala" (SNAP) och "temporala" (SPAN) termer. I artikeln diskuteras utförligt olika sorters relationer som kan förekomma mellan termer, både inom samma kategori (SNAP eller SPAN) och mellan kategorierna. I artikeln beskriver författarna också ett praktiskt exempel där man vill bygga upp en formell ontologi för situations- och hotbedömning i katastrofområden.

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[36] G Fenza, D Furno, V Loia och M Veniero. Agent-based Cognitive approach to Airport Security Situation Awareness. Proc. Int. Conf. on Complex, Intelligent and Software Intensive Systems (CISIS), 2010.

[37] U Inyaem, P Meesad, C Haruechaiyasak, D Tran. Construction of Fuzzy Ontology-Based Terrorism Event Extraction. Proc. Int. Conf. on Knowledge Discovery and Data Mining, 2010. WKDD '10, s. 391 – 394.

[38] E G Little och G L Rogova. Designing ontologies for higher level fusion. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s. 70-82.

Hull[39] et al beskriver en metodik som utvecklats för att (semi-) automatiskt märka eller "tagga" meddelanden i ett informationssystem. Informationssystemet i det aktuella fallet är ett system där olika sorters "kriminell aktivitet" rapporteras in av mänskliga operatörer. Med hjälp av den automatgenererade taggen och en ontologi som är utvecklad för ändamålet är tanken att det ska bli lättare att finna önskad information, exempelvis. uppgifter om bilstölder i ett specifikt område, vid sökningar i systemet. Fokus i artikeln ligger på hur man avgör om ett meddelande ska klassificeras med en viss "tag". I artikeln använder man sig av en kombination av meningsbyggnad och nyckelord för att göra själva klassificeringen. Resultat från experiment med konstruerade såväl som verkliga data presenteras i artikeln.

Ett system kallat Multi-Intelligence Tool Suite (MITS) beskrivs av Auger[40]. Här kan en text analyseras parallellt av flera processer, en för varje kunskapsdomän där innehåll kan komma att påträffas i dokumentet, som var och en har tillgång till en egen "knowledge cartridge" med domänontologi, inferensregler, mönster-matchningsregler etc. Domänontologierna byggs med ett tidigare utvecklat system Semi-Automatic Construction of Ontologies from Texts (SACOT), som baserar sig på en jämförelse mellan frekvenserna av ord i två corpora (textmassor): en referenscorpus samt en domäncorpus producerad av SMEs. Ur detta produceras RDF-triplar[41] som representerar de funna relationerna mellan orden.

Barwise och Devlins situationsteori refereras kort i en artikel av Kokar[42] et al. I den formaliseras information om en situation i s.k. *infoner*. En infon $<<R, a_1, a_2, a_3 ,…, a_n, 0/1>>$ uttrycker en relation R mellan ett antal objekt $a_1, a_2 , a_3 ,…, a_n$. Det sista värdet 0 eller 1 är en s.k. polaritet som uttrycker om infonen är sann (1) eller falsk (0). Infoner kan kombineras med logiska konnektiv till sammansatta infoner. En situation kan sägas stödja en viss infon om det går att säga att utifrån situationen är en viss infon eller kombination av infoner sanna (1). Utifrån detta ramverk samt ontologibeskrivningsspråket OWL bygger författarna en Situation Theory Ontology (STO, se sid 15), som sedan tillämpas för att beskriva en

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[39] R D Hull, L Lashine och D Jenkins. Semantic enrichment of multi-intelligence data within a net-centric environment. Proc. SPIE, Vol. 7345, 734509 (2009).

[40] A Auger. Acquisition and Exploitation of Knowledge for Defence and Security. NATO RTO IST-087 Symposium on Information Management – Exploitation, Försvarshögskolan, Stockholm, Oktober 2009.

[41] RDF – Resource Description Framework, ett språk, ofta uttryckt i XML-representation, för att beskriva relationer mellan objekt, exempelvis i en ontologi.

[42] M M. Kokar, C J Matheus och K Baclawski. Ontology-based situation awareness. Information Fusion Volume 10, Issue 1, January 2009, Pages 83-98.

situation med olika aktörer som har fokus på olika delar av situationen. Artikelns budskap är att föreslå en semantik anpassad för datorinferens som är kompatibel med både situationsteori och Endsleys modell av mänskligt situations-uppfattande.

S.k. semantiska wikis, wikisystem där lagring och inbördes länkning av samt sökning efter information kan göras enligt idéer hämtade från semantic web har skapat stort intresse de senaste åren. Ulicny[43] et al presenterar sitt prototypsystem som de kallar Semantic Wiki Alerting Environment (SWAE). Syftet med det är att samla in information från öppna källor inklusive sociala media för att automatiskt skapa modeller över transnationella kriminella gäng. Informationen som samlas in inkluderar medlemmar, grupper, platser, händelser och aktiviteter. Systemet baseras på en semantisk wiki men med tillägget att det förbehandlar data från olika källor och extraherar relevant semantisk information d.v.s. metadata och implicita relationer. De har även lagt till ett alarmgränssnitt där användare kan prenumerera på olika sorters information. Systemet bygger på en egenkonstruerad ontologi som formaliserar kriminella gäng och deras inre och externa relationer. Vidare implementeras NATO STANAG 2022 mått för källtillförlitlighet och -trovärdighet som de använder för taggning av informationen.

Reininger[44] et al har också utvecklat ett system som använder sig av en semantisk wiki. Deras tillämpning är inriktad mot militära informations-operationer och har många gemensamma drag med Ulicny et al. Detta system verkar dock vara något mer utvecklat och de har kopplat på Analyst's Notebook för att visualisera länkar mellan individer samt Google maps för att visualisera händelser och var personer befinner sig. Inläsning av data sker genom en kombination av automatiska metoder (entitetsextraktion) samt användar-validering. Likt Ulicny et al utnyttjar också de en ontologi men denna används endast informellt (vid användarvalideringen) då de i sin tillämpning inte har funnit något behov av inferens.

Vid analys av data och inferens över fakta kan det för många tillämpningar vara av intresse att veta vilken information som var känd när. I en artikel av Emmons och Reid[45] tar författarna upp en metod för att lägga till temporal information vid annotering av data. De möjliggör tidsberoende vyer av kunskapsbasen samt spårbarhetsmöjligheter. Vidare har de infört en omskrivningsmodul för

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[43] B Ulicny, C J Matheus och M M Kokar. A semantic wiki Alerting Environment Incorporating Credibility and Reliability Evaluation. STIDS 2010.

[44] D Reininger, D Ihrie, och B Bullard. Semantic Wiki for Visualization of Social Media Analysis. STIDS 2010.

[45] I Emmons och D Reid. Maintaining Temporal Perspective. STIDS 2010.

SPARQL-frågor[46] som utökar frågan med att även ta hänsyn till tidsinformationen. Omskrivningen förändrar inte ursprungsfrågans logik och returnerar både det som eftersöks samt tillhörande informationsförändringar.

Balakrishna och Munirathnam[47] presenterar ett bibliotek för semiautomatisk ontologigenerering med fokus på underrättelsehantering. Då ontologigenerering är en tidskrävande process, och än mer så för icke-triviala domäner, finns det ett stort behov av metoder som underlättar byggandet av ontologier. I USA har man identifierat 33 huvudämnen inom underrättelseområdet och författarna har fokuserat på byggandet av ontologier för dessa. Genereringen av ontologibiblioteket för de 33 ämnena har fem huvudsteg. I det första har man samlat ca 500 dokument som hör till ett enskilt ämne. I steg två tillhandahåller man frön som systemet kan utgå från vid extraktionen av relevanta meningar. I steg tre utför man processning av texten, d.v.s. entitetsextraktion, s.k. Part-of-speech-taggning, word-sence disambiguation, etc. med syftet att upptäcka koncept och deras relationer. Fjärde steget inbegriper att man skapar koncepthierarkier samt löser ut konflikter som kan ha uppstått i det förra steget. I slutsteget för man samman ontologier som överlappar. Då systemet är tänkt att kunna köras repetitivt och uppdatera ontologierna vartefter ny information dyker upp kommer det att skapas olika ontologier vid olika tidpunkter. Slutsteget finns där för att utöka de gamla ontologierna med den nya informationen. I artikeln presenterar författarna även mätetal för utvärdering av ontologigenereringen.

Baumgartner[48] et al behandlar ett ontologibaserat ramverk som syftar till att ge operatörer en bättre situationsmedvetenhet i krissituationer. Systemet de har byggt är baserat på att man kontinuerligt samlar in information från ett antal olika källor. För enkelhetens skull är dessa källor baserade på enskilda domänontologier. Sedan har de ontologier som översätter mellan dessa olika domäner. En annan modul i systemet resonerar över den information som kontinuerligt kommer in och triggar om en regel för någon krissituation uppfyllts. Om så sker larmas systemet för situationsmedvetenhet så operatören görs medveten om den uppkomna situationen. Systemet har utvärderats i ett trafikscenario baserat i Österrike. Systemet får information från flera håll som meddelar om pågående trafikarbeten, trafikstockningsinformation, incidenter samt en radiostation med nationell täckning. Fördelen med systemet är att det lyckas integrera information från flera källor samt även lyckas koppla objekt i den verkliga världen via spatiala och temporala relationer. Dock kräver det dels

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[46] SPARQL är ett frågespråk för det tidigare omnämnda RDF – Resource Description Framework..

[47] M Balakrishna och M Srikanth. Automatic Ontology Creation from Text for National Intelligence Priorities Framework (NIPF). OIC 2008.

[48] N Baumgartner, W Gottesheim, S Mitsch, W Retschitzegger och W Schwinger. BeAware!— Situation awareness, the ontology-driven way. Data & Knowledge Engineering, Vol. 69, Nr. 11, November 2010, s. 1181-1193.

att det finns domänexperter tillgängliga, dels att regler skapas för alla situationer. Ett mycket tidskrävande arbete samt tyvärr något som gör det ganska oflexibelt då situationer som det inte finns en regel för följaktligen inte kan "upptäckas".

Blasch[49] et al beskriver ontologifusion eller "alignment", dvs hur delvis överlappande ontologier byggda för olika syften skall kunna samordnas och integreras semantiskt. Problemet måste hanteras när man skall försöka utbyta information mellan olika system och bevara det semantiska innehållet, det kan röra olika nationers ledningssystem såväl som ontologier över medicinska begrepp, beskrivningar av komponenter till olika fordon e.t.c. Området har snabbt fått ökad uppmärksamhet de senaste åren. I Blasch et al tar man upp maritim övervakning där både "hard" och "soft" information från olika kanadensiska myndigheter skall sambearbetas: Information från GIS-system, identitetsinformation, radar, väderprognoser etc. Det konstateras att problemet inte är helt lättlöst, och många osäkerheter kvarstår, såsom hur osäkerhet i ontologier skall jämföras och förmedlas. Bidraget har en ganska stor referenslista med intressanta referenser inom området.

Slutligen kan ett sensorrelaterat bidrag nämnas där Guo[50] et al beskriver hur klassificering av fordon från akustiska signaler kan förbättras genom att inkludera domänkunskap som formaliseras i ontologier, samt genom inlärning och association av semantiska attribut i inlärningen, "Semantic Enrichment", ung. semantisk anrikning eller -förädling.

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[49] E Blasch, E Dorion, P Valin, E Bossé och J Roy. Ontology alignment in geographical hard-soft information fusion systems. Fusion 2010.

[50] B Guo, M Nixon och T Damarla. Acoustic vehicle classification by fusing with semantic annotation. Fusion 2009.

6 Fusion i Semantiska nätverk

Semantiska nätverk (SN), introducerade för datorer redan på 50-talet, är ett intressant sätt att beskriva situationer och relationer, och de lämpar sig därför bra för situationsanalys. De relaterar också starkt till bl.a. ontologier. Dock har referaten av några artiklar där de har större vikt fått ett eget kapitel här.

Ett system som baserat på lingvistiska mönster extraherar intressant information ur text presenteras av Laudy och Goujon[51]. Det hela baseras på en ontologi kring området texterna beskriver (i detta fall ett uppror i Elfenbenskusten) och s.k. konceptuella grafer. Den grafiska formalismen i dessa baseras på SN tmen kan direkt översättas till första ordningens predikatlogik. Likheter kan mätas mellan sådana grafer som skapats utifrån olika rapporter för att se om de kanske beskriver samma information eller händelse och således kan föreslås till operatören av systemet att övervägas för fusionering. I en relaterad artikel av Laudy och Ganascia[52] fokuserar författarna inte på själva fusionen av två grafer med överlappande innehåll, utan på svårigheterna att avgöra huruvida två informationsgrafer representerar två observationer av samma händelse (alternativt nära relaterade händelser), d.v.s. om graferna är "kompatibla" och kan fusioneras, eller om de representerar information om två helt olika händelser och är inkompatibla. I artikeln redogör författarna för hur de har valt att beräkna likheten mellan två "koncept".

I James Llinas forskningsgrupp vid Universitetet i Buffalo har man på ett snarlikt sätt specialiserat sig på att beskriva situationer och det semantiska innehållet i mänskligt genererad information (huvudsakligen text) i form av SN där man letar efter delsituationer med hjälp av grafmatchningsmetoder[53,54]. I ännu ett bidrag därifrån[55] diskuteras olika osäkerhetsrepresentationer och transformationer mellan dessa för att göra dem jämförbara. De presenterar i en annan artikel[56] ett

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[51] C Laudy och B Goujon. Soft data analysis within a decision support system. Fusion 2009.

[52] C. Laudy och J.-G. Ganascia. Introducing Semantic Knowledge in High-Level Fusion. Proc. IEEE conference on Military communications, MILCOM, 2009.

[53] A Stotz, R Nagi och M Sudit. Incremental graph matching for Situation Awareness. Fusion 2009.

[54] K Sambhoos, R Nagib, M Sudit och A Stotz. Enhancements to high level data fusion using graph matching and state space search. Information Fusion, Volume 11, Issue 4, October 2010, p. 351-364.

[55] G Gross, R Nagi och K Sambhoos. Soft information, dirty graphs and uncertainty representation / processing for situation understanding. Fusion 2010.

[56] M Hannigan, D McMaster, J Llinas och K Sambhoos. Data association and soft data streams. Fusion 2010.

arbete med att kunna göra jämförelser av likhet mellan olika noder och länkar i ett litet "test"SN med olika delar av ett större SN (för att hitta delar i det som liknar testSN). Då behövs, som nämnts ovan, en form av semantisk metrik för nätverksstrukturen, något som diskuteras ingående efter att man gjort en litteraturstudie i ämnet. Man använder därefter den algoritm, TruST (truncated search tree), man tidigare utvecklat för att lösa matchningsproblemet. Ett snarlikt bidrag av Prentice[57] et al beskriver ett system "Tractor" där man från textmeddelanden som analyserats med Natural Language Processing (NLP) mjukvaran GATE kan skapa ett SN som beskriver semantiken i textmeddelandena.

Att i stora datamängder automatiskt kunna identifiera entiteter eller objekt som avviker från övriga är en viktig förmåga för bland annat underrättelseanalytiker. Ett exempel på användningsområde för algoritmer som kan hantera den typen av problem är identifikation av misstänkta personer som kan vara värda att undersöka närmare i brottsutredningar. Lin och Chalupsky[58] poängterar dock behoven av att inte bara kunna få ut en sådan lista av potentiella anomalier att titta närmare på, utan att också kunna erbjuda en förklaringsmodell till varför de utvalda objekten blivit klassade som anomalier. Denna typ av förklarings-modeller är viktiga, då de underlättar för en mänsklig användare att avgöra huruvida en utpekad anomali är värd att arbeta vidare med, eller om det är ett uppenbart falsklarm. Den datastruktur de valt att arbeta med är SN, bestående av ett flertal olika relationer mellan de ingående objekten, där semantiken hos kanter (dvs. relationer) i grafen tas i beaktande, vilket kan jämföras med metoder för social nätverksanalys där inte någon hänsyn tas till semantiken i nätverket.

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[57] M Prentice, M Kandefer och S C Shapiro. Tractor: a framework for soft information fusion. Fusion 2010.

[58] Shou-de Lin and H Chalupsky. Discovering and Explaining Abnormal Nodes in Semantic Graphs. IEEE Transactions on Knowledge and Data Engineering, Vol. 20, Nr. 8, Augusti 2008.

7 Anomalidetektion

Forskningsområdet anomalidetektion där man försöker att upptäcka objekt eller beteenden som avviker från "normalbilden" är för tillfället ett hett område inom informationsfusionsvärlden. Mycket handlar om att upptäcka anomalier hos olika farkoster, såsom fartyg på havet och flygplan i luften, något som flera av nedanstående artiklar handlar om. Men området är naturligtvis viktigt för all form av övervakning till vilken sensor- och fusionssystem levererar information.

Brax[59] et al. har tillämpat anomalidetektionstekniker på målspår extraherade från videoövervakningsdata inspelade i avgångshallen på en flygplats, med syfte att detektera människor med avvikande beteende (exempelvis ficktjuvar och potentiella terrorister). Två anomalidetektionsmetoder baserade på olika typer av teknologier har utvecklats, och författarna pekar på att precisionen i klassificeringarna kan förbättras genom att fusionera resultaten från de två metoderna. Ett problem är dock att en relativt hög falsklarmstakt erhålls, d.v.s. att många normala beteenden blir klassificerade som anomalier. Detta förklarar författarna framförallt med att det finns brister i det underliggande målföljningssystemet, och att det är en mycket tät miljö där människor uppträder mer eller mindre slumpmässigt.

Anomalidetektionstekniker presenteras ofta som väldigt viktiga för att stödja mänskliga operatörer med att uppnå en bättre situationsmedvetenhet inom den maritima domänen. Dock diskuteras sällan vilken typ av anomalier, aktiviteter, eller situationer som operatörerna behöver stöd med. I en artikel av van Laere och Nilsson[60] presenteras resultaten från en workshop med maritima domän-experter, där syftet varit att identifiera de händelser där operatörerna har behov av ett aktivt stöd för så kallade "early warnings". Exempel på sådana händelser som identifierats är oljeläckage, fiske i förbjudna zoner, kapningar, samt försök att manipulera den AIS[61]-transponder som finns ombord på fartygen.

Ett exempel på en anomalidetektionsteknik som kan appliceras på den maritima domänen presenteras av Lane[62] et al. Dessa forskare har utvecklat en statistisk metod som har möjlighet att hantera osäkerhet i de indata som används till

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[59] C Brax, L Niklasson och R Laxhammar. An ensemble approach for increased anomaly detection performance in video surveillance data. Fusion 2009.

[60] J van Laere och M Nilsson. Evaluation of a workshop to capture knowledge from subject matter experts in maritime surveillance. Fusion 2009.

[61] Automatic Identification System (AIS) är ett system som gör det möjligt att identifiera och följa ett fartygs rörelser från andra fartyg.

[62] R O Lane, D A Nevell, S D Hayward och T W Beaney. Maritime anomaly detection and threat assessment. Fusion 2010.

algoritmen. Fem separata anomalidetektorer har implementerats, där varje detektor ansvarar för att upptäcka ett av fem identifierade anomala beteenden (avvikelse från förväntad rutt, oväntad AIS-aktivitet, oväntad ankomst till hamn, väldigt nära passage till annat fartyg, samt inträde i en fördefinierad zon). Genom att fusionera utdata från dessa detektorer med hjälp av ett Bayesianskt nätverk erhålls även klassificering på en högre nivå som avgör om fartyget bedömds utgöra ett hot eller ej.

En annan föreslagen teknik inom den maritima domänen, som även den bygger på Bayesianska nätverk, har presenterats av Fooladvandi[63] et al. Målet med deras studie är att detektera specifika fartygsaktiviteter, såsom lotsning av fartyg. Deras framtagna modell är uppbyggd utifrån expertkunskap, och den föreslagna tekniken har utvärderats på riktig AIS-data. Tekniken har visat sig vara väl fungerande, men liksom för en del andra tekniker har problem med en hög falsklarmstakt uppstått. Denna typ av problem måste lösas för att användaren av systemet skall kunna förväntas få en tillräckligt hög tilltro till systemet.

Med syfte att stödja utvecklandet av bättre framtida anomalidetektionssystem har Riveiro[64] et al. studerat den analysprocess som utförs av mänskliga operatörer i dagens system. I en serie studier har forskarna studerat operatörer som arbetar vid olika svenska och utländska VTS[65]-centraler i dess dagliga arbete. Denna typ av studier är viktiga då de sätter fokus på att den anomalidetektionsförmåga som efterfrågas i första hand är tänkt att stödja de mänskliga operatörerna i sitt arbete, snarare än att ersätta dessa med helautomatiska lösningar.

Många typer av anomalidetektionsalgoritmer har på senare år utvecklats, men ett återkommande problem är hur dessa algoritmer egentligen skall utvärderas. Laxhammar[66] et al föreslår en metod för jämförelse av prestanda hos anomali-detektionsalgoritmer, baserat på hur lång tid det tar för algoritmerna att känna av att ett målspår från träningsdata har brutits och ersatts med ett mer slumpmässigt beteende. På detta sätt undersöks hur snabbt algoritmerna kan detektera avvikelser från normalbilden, utan att riskera att de skräddarsys för att upptäcka specifika på förhand bestämda typer av situationer. De två testade statistiska

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[63] F Fooladvandi och C Brax. Signature-based activity detection based on Bayesian networks acquired from expert knowledge. Fusion 2009.

[64] M Riveiro, G Falkman, T Ziemke och T Kronhamn. Reasoning about anomalies: a study of the analytical process of detecting and identifying anomalous behavior in maritime traffic data. Proc. SPIE, Vol. 7346, 73460A (2009).

[65] Vessel Traffic Service (VTS) är en form av marint övervakningssystem snarlikt flygets Air Traffic Control (AIS).

[66] R Laxhammar, G Falkman och E Sviestins. Anomaly detection in sea traffic - a comparison of the Gaussian Mixture Model and the Kernel Density Estimator. Fusion 2009.

algoritmerna uppvisar båda oväntat dålig prestanda, men huvudbidraget här är utvärderingsmetodiken snarare än implementeringen av de specifika algoritmerna.

Inom området anomalidetektion bör det även nämnas att omfattande verksamhet bedrivs i Sverige vid Swedish Institute of Computer Science (SICS). Dock har inga resultat därifrån publicerats under de granskade åren.

8 Social nätverksanalys (SNA)

Hot mot vårt moderna samhälle är ofta inte hierarkiskt uppbyggda, utan tenderar mer och mer att bli distribuerade och decentraliserade. Ett exempel på sådana decentraliserade strukturer är olika typer av terrornätverk, där de ingående medlemmarna i nätverken ofta endast har kännedom om sina närmaste delar av nätverket. För att mer effektivt kunna möta denna typ av hot krävs en bättre förståelse för hur nätverken är uppbyggda, vilka som ingår i dem, samt vilka personer som är viktiga eller centrala för nätverkets syfte. Detta är några av de frågeställningar som hanteras i så kallad social nätverksanalys (SNA). Inom SNA visualiseras ett socialt nätverk med hjälp av grafteori, där noderna i grafen representerar individer/aktörer, och där kanter mellan noder representerar relationer/interaktioner mellan noderna (exempelvis i form av kommunikation eller nära släktskap mellan aktörerna).

Traditionellt så har de analyserade nätverken inom SNA tagits fram utifrån information från mänskliga källor, men i takt med att tillgänglig sensordata ökar allt mer har ett behov att kunna identifiera nätverksstrukturen utifrån både hård sensordata (t.ex. videoövervakning, telefonavlyssning, RFID-taggar) och mer mjuka sensordata (t.ex. HUMINT[67] och nyheter) framkommit. Josephson[68] et al diskuterar hur information från olika typer av sensorer kan fusioneras i syfte att automatiskt identifiera nätverksstrukturer. Dessa ger också ett illustrativt exempel på hur olika typer av sensordata kan användas för en förbättrad underrättelseanalys.

Stocco[69] et al undersöker hur SNA-tekniker kan användas för att följa små grupperingar i dataströmmar genererade via Twitter. Vad som är mest intressant med detta arbete ur forskningssynpunkt är att det fokuserar på dynamisk SNA, d.v.s. att sociala nätverk som förändras över tid tas i beaktande. Inom traditionell SNA antas det annars ofta att nätverken har en statisk struktur, vilket ofta är ett ganska starkt antagande som inte alltid överensstämmer med verkligheten.

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[67] HUMINT – Human intelligence; Underrättelser som baseras på information inhämtad från människor, inte sensorer.

[68] J Josephson, J Eckroth och T Miller. Estimation of adversarial social networks by fusion of information from a wide range of sources. Fusion 2009.

[69] G Stocco, R Savell och G Cybenko. Dynamic social network analysis using conversational dynamics in social networking and microblogging environments. Proc. SPIE, Vol. 7666, 766606 (2010).

I en mycket intressant artikel av Zhu[70] et al behandlas problematiken med att visualisera sociala nätverk på ett sätt som effektivt stödjer analytikern med att tolka strukturella komponenter av nätverket för att bland annat hitta grupperingar inom det. Traditionella visualiseringsalgoritmer för sociala nätverk är anpassade för att göra dem lättöverskådliga, men stödjer inte tolkning av strukturella komponenter på ett effektivt sätt. Zhu et al föreslår därför en alternativ visualiseringsmetodik som bygger på användandet av så kallade självorganiserande kartor (eng. self-organizing maps). En utvärdering på data extraherad från en databas över kriminella visar tydligt på fördelen med den föreslagna metodiken för vissa typer av analysproblem.

Artikeln "Finding a Team of Experts in Social Networks" av Lappas[71] et al behandlar, som rubriken antyder, problemet att ur ett nätverk med personer försöka hitta den grupp som är bäst lämpad att tillsammans lösa ett problem. Lämpligheten hos de ingående individerna i gruppen avgörs inte bara av deras expertis utan även av hur bra de kan samarbeta och kommunicera med varandra. Författarna gör antagandet att personerna antingen har en förmåga till detta eller inte, men påpekar att problemet är enkelt att utöka till en glidande förmågeskala. I sin ansats är de ute efter att hitta en grupp personer som är så liten som möjligt samt där kommunikationskostnaden är så liten som möjligt. Problemet författarna tar upp är relevant vid alla personalplaneringssituationer. De visar att detta är ett s.k. NP-svårt problem och föreslår en algoritm som ger en approximativ lösning. De har utvärderat sina resultat både teoretiskt samt genom att testa på ett verkligt scenario. Där använder de sig av Citeseer samt DBLP[72] som källor och försöker hitta grupper med artikelförfattare som skulle kunna vara lämpliga för att samarbeta kring olika sorters algoritmer.

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[70] B Zhu, S Watts, and H Chen. Visualizing social network concepts. Decision Support Systems, Vol. 49, Nr. 2, Maj 2010, s. 151-161.

[71] T Lappas, K Liu och E Terzi. Finding a Team of Experts in Social Networks. KDD 2009.

[72] Citeseer – ett digitalt bibliotek med vetenskapliga artiklar inom data- och informationsvetenskap med tillhörande sökmotor. DBLP – en webresurs i form av av bibliografisk information om datavetenskapliga tidskrifter och konferensproceedings.

9 Textanalys

Att hitta relevant information i stora textvolymer har länge varit ett forsknings-område som växt, och det anknyter starkt till informationsfusionens "mjuka" sida eftersom den informationen i praktiken alltid är genererad av människor. Att få text strukturerad och klassificerad efter innehåll, viktiga ord och meningar markerade, olika texter associerade avseende det de beskriver etc är något datorer idag blivit ganska duktiga på med moderna textanalysmjukvaror. Ett stort användningsområde är exempelvis OSINT[73]: underrättelseanalys av exempelvis nättidningar, webbsidor, bloggar etc. vilka är källor som producerar enorma textvolymer varje dygn runt om i världen.

Text Insight via Automated Responsive Analytics (TIARA)[74], är ett textanalys-system som kan visualisera stora mängder texter. Med hjälp av innehållsanalys sammanfattar man texterna till en mängd ämnen. Systemet är uppbyggt av två huvuddelar där den ena arbetar "off-line" och den andra "on-line". I den första delen samlas dokument från filsystem eller databaser in. Dokumenten rensas sedan från irrelevant data och skickas till ämnesanalysmodulen som tar fram nyckelordsdistributionen i enskilda dokument samt ämnesdistributionen över dokumenten. On-line-delen triggas av att en användare skickar in en fråga, t.ex. en nyckelordssökning. I botten av systemet finns en Lucene-sökmotor som används för att identifiera relevanta dokument. Från dessa dokument extraherar man sedan, m.h.a. den distributionsstatistik som tidigare sammanställts, automatiskt dokumentens huvudnyckelord och ämnen samt visualiserar dem. Forskarna har använt TIARA för två tillämpningar. Det ena är visualisering av e-post-sammanfattningar och det andra är analys av patientjournaldata.

I en artikel av Shahaf och Guestrin[75] presenteras en metod och algoritm för att koppla ihop nyhetsartiklar i en logiskt sammanhängande kedja. Användarna kan ange två teman, t.ex. bostadslån och ekonomisk kris, och fråga hur dessa hänger ihop. Författarnas metod returnerar en kedja av artiklar som visar hur det första temat hänger ihop med det andra. Författarnas huvudbidrag är att de presenterar ett sätt att formalisera kännetecknen hos en bra historia (kedja av artiklar) så att den är koherent, samt att de presenterar en algoritm för att åstadkomma detta. De lyckas även med att mäta ingående artiklars påverkan på varandra utan att det finns direkta länkar mellan dem. Sättet de formaliserar problemet på är genom att betrakta det som ett optimeringsproblem, i detta fall ett s.k. linjärt program.

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[73] OSINT - Open Source Intelligence; Underrättelser som baseras på information från öppna källor (dagstidningar, tidskrifter, websidor e.t.c.)

[74] F Wei, S Liu, Y Song, S Pan, M X Zhou, W Qian, L Shi, L Tan och Q Zhang. TIARA: A Visual Exploratory Text Analytic System. KDD 2010.

[75] D Shahaf och C Guestrin. Connecting the Dots Between News Articles. KDD 2010.

Utvärderingen har gjorts via en användarstudie och genom att dels jämföra med Google News Timeline, dels den rättframma metoden av "kortast väg". Kortast väg-metoden är det naiva sättet att angripa problemet, vilken går ut på att man tar alla artiklar och skapar en graf där noderna utgörs av artiklarna och kanterna är cosinuslikheten[76] på hur lika artiklarna är.

Många textklustringsalgoritmer är baserade på direkt matchning mellan ord. En nackdel med denna metod är att texter kan vara semantiskt lika även om de inte innehåller samma ord. En alternativ metod för textklustring som baserar sig på en fördefinierad ontologi presenteras av Cheng[77]. Den presenterade metoden förutsätter dock att man redan från början har en tämligen god kännedom om innehållet i textdokumenten.

En artikel av Hu[78] et al handlar om att klustra dokument i grupper. Målet är att få dokument som handlar om samma eller liknande saker att hamna i samma grupp. Problemet är att olika författare kanske använder olika ord för att beskriva samma sak, vilket i sin tur kan leda till att dokument felaktigt grupperas in i olika grupper. Området är relevant då det är av intresse att ur en stor mängd dokument snabbt kunna hitta de dokument som hör till ett visst tema. Den traditionella metoden för att klustra dokument är att betrakta dem som påsar med ord och med hjälp av en ontologi, t.ex. WordNet, matcha orden mot ontologikoncept och antingen ersätta orden i dokumentet med ontologikoncepten eller lägga till ontologikoncepten till dokumenten. Ett problem med denna ansats är att det kan vara svårt att hitta en ontologi som täcker orden i dokumenten. Vidare kan användandet av ontologikoncept leda till att man ökar mängden irrelevant information och därmed gör klustringen svårare. Författarna föreslår istället att man använder sig av Wikipedia som extern källa. De påpekar att i Wikipedia beskriver de individuella artiklarna endast ett tema i taget. Innehållet i Wikipedia är ofta uppdaterat och har en mycket stor täckning. Rubriken på varje wikipediaartikel skulle kunna jämföras med ett ontologikoncept och länkarna mellan wikipediaartiklarna kan jämföras med relationer mellan ontologikoncept. Författarna utvärderar sin ansats genom att testa sju olika sorters klustrings-scheman i tre olika typer av datamängder.

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[76] Eng. "Cosine similarity", se http://en.wikipedia.org/wiki/Cosine_similarity. Detta är ett mått på likheten mellan två vektorer av *n* dimensioner genom att beräkna cosinus för vinkeln mellan dem, vilket ofta används för att jämföra olika dokument funna genom Textmining.

[77] Y Cheng. Ontology-Based Fuzzy Semantic Clustering. Proc. Int. Conf. on Convergence and Hybrid Information Technology (ICCIT), 2008, s. 128 - 133.

[78] X Hu, X Zhang, C Lu, E. K. Park och X Zhou. Exploiting Wikipedia as External Knowledge for Document Clustering. KDD 2009.

Jenge[79] et al behandlar i en artikel från ett NATO RTO Symposium bearbetningen av HUMINT-underrättelserapporter. Syftet är att samla och formalisera information som kan ligga till grund för identifiering av hot. Genom att sammanställa information från flera rapporter kan de med sitt system känna igen hotsituationer. I artikeln beskriver författarna den del av systemet som analyserar naturligt språk, d.v.s. entitetsextraktion samt ytlig parsning. Genom att använda sig av en ontologi kan de klassificera information och avgöra om det passar in i någon av deras hotmodeller.

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[79] C Jenge, S Kawaletz och U Schade. Combining Different NLP Methods for HUMINT Report Analysis. NATO RTO IST-RSY-087 on Information Management – Exploitation, Försvarshögskolan, Stockholm, Oktober 2009.

10 Underrättelseanalys

Detta är ett område där många organisationer håller på sina egenutvecklade verktyg och de datalogiska angreppssätt som de använder och inte gärna publicerar information om dem. Underrättelsetjänsterna idag har att hantera mer heterogen information än under det kalla kriget, och de tillgängliga informationsvolymerna ökar ständigt. Även stora företag bedriver ofta omvärldsanalyser som är snarlika ren underrättelsetjänst. Många mjukvaru-verktyg inom detta område strävar mot att vara gemensamma användargränssnitt mot andra, var och en mer specialiserade mjukvaror såsom verktyg för textanalys, web- och data mining, geografisk informationshantering (GIS), koppling mot biblioteksdatabaser samt mot olika myndigheters databaser. De är ofta även formgivna att stödja grupper av var för sig specialiserade användare som arbetar mot en gemensam databas, samt att stödja den vanligt förekommande underrättelseprocessen: inhämtningsstyrning, inhämtning, kollationering (strukturering) av inhämtad information, analys samt delgivning av färdiga underrättelser till chefer att nyttja som beslutsunderlag.

Ett bra exempel på detta är demonstratorn Common Standardised User Interface" (CSUI)[80] som tagits fram av the EU:s försvarsmyndighet European Defence Agency (EDA). I november 2009 demonstrerades hur modern datateknik kan stödja transnationell underrättelsetjänst genom att erbjuda en enhetlig miljö där de ovan beskrivna förmågorna kan nås från ett enda användargränssnitt. Reaktionerna på verktygen från närvarande underrättelseexperter var goda, och man avsåg att gå vidare och utveckla det till en prototyp.

Tecuci[81] et al beskriver ett försök att skapa en miljö för beslutsfattande och problemlösande där man strävar efter att människan och datorn arbetar tillsammans för att kunna utnyttja varandras styrkor och täcka upp för varandras svagheter (så kallad mixed-initiative reasoning, vilket andra ovan refererade artiklar också tagit upp). Resultatet av deras forskning är Disciple (lärjunge) vilket inbegriper teori, metodik och en uppsättning verktyg för att skapa lärande mjukvaruagenter. Ett flertal experimentella agenter har skapats för att stödja beslutsfattare i domäner såsom underrättelseanalys och krishantering, där agenten tränas upp genom att experten skapar resonemangsträd för att analysera specifika hypoteser. Mer forskning återstår, men det är intressant att se hur det

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[80] EDA Bulletin Nr. 13, Februari 2010. Se http://www.eda.europa.eu/WebUtils/downloadfile.aspx?fileid=843, sidan 13 – 15. (weblänk giltig november 2010).

[81] G Tecuci, D Marcu, M Boicu, Vu Le. Mixed-Initiative Assumption-Based Reasoningfor Complex Decision-Making. Studies in Informatics and Control, December 2007, Volume 16, Number 4, pp. 459-468.

eftersträvas att skapa ett samarbete mellan människa och maskin som liknar det samarbete som sker mellan människor som arbetar i grupp.

Ett mer konkret exempel på användandet av Disciple ges i Schum[82] et al, där den så kallade kognitiva assistenten Disciple-LTA presenteras. Disciple-LTA stödjer underrättelseanalytiker med att besvara troligheten för att olika hypoteser är sanna, såsom att "Al Qaeda har tillgång till kärnvapen". Detta görs genom att övergripande hypoteser bryts ner till enklare hypoteser, för vilka man letar efter information (evidens) som stödjer eller talar emot dessa enklare hypoteser. Genom att kombinera sådan information så erhålls ett mått på troligheten för olika enkla hypoteser fram, vilka sedan kombineras till ett mått på troligheten hos den ursprungliga övergripande hypotesen. Utöver att användas för att stödja underrättelseanalytiker med själva analysen har Disciple-LTA också använts för att lära ut evidensbaserade resonemang till nya underrättelseanalytiker. Detta har gjorts med hjälp av TIACRITIS[83], i vilket användaren aktivt får lära sig att söka efter evidens som kan stärka eller förkasta olika hypoteser.

En studie i hanteringen av tilltro till underrättelsekällor har gjorts av Nevell[84] et al. Tilltro brukar delas upp i "Reliability" (Tillförlitlighet för en källa) och "Credibility" (Sakriktighet hos informationen från källan). Ett Bayesisianskt nätverk utvidgat med möjligheter att ta hänsyn till dessa två osäkerhetsmått används. Ett enkelt simulerat scenario i form av observationer av komponent-leveranser till bilfabriker i en stad har använts, och underrättelsefrågan som ställdes var i vilken fabrik vilken typ av bil tillverkades. Man konstaterar att det ger ett analysresultat som stämmer bättre med verkligheten än om man inte tagit denna hänsyn.

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[82] D Schum, G Tecuci, M Boicu och Dorin Marcu. Substance-Blind Classification of Evidence for Intelligence Analysis. OIC 2009.

[83] G Tecuci, M Boicu, D Marcu, D Schum, och B Hamilton. TIACRITIS System and Textbook: Learning Intelligence Analysis through Practice. STIDS 2010.

[84] D Nevell, S Maskell, P Horridge och H Barnett. Fusion of data from sources with different levels of trust. Fusion 2010.

11 Gemensam lägesinformation samt något om sensornätverk

Vid internationella insatser och operationer krävs ofta en samverkan mellan flera olika typer av förband, inte sällan bestående av enheter från flera olika nationer. Detsamma gäller för olika myndigheter och organisationer i nationella eller internationella krissituationer. För att samverkan och interoperabilitet ska kunna uppnås krävs väl fungerande kommunikation och att det går att uppnå en gemensam förståelse för läget. Ofta används begreppet lägesbild, som dock är problematiskt[85]. Att uppnå gemensam förståelse är svårt, inte minst på grund av att enheternas system vanligtvis är utvecklade som traditionella stuprörs-lösningar. Området är viktigt för informationsfusionen eftersom lägesinforma-tionen oftast blir mer komplett och lättförståelig ju fler källor, gärna heterogena sådana, som levererar information till den, källinformation som då måste associeras och fusioneras för att inte bli ohanterligt stor. Här refereras några specifika artiklar inom området, men många artiklar i de övriga kapitlen beskriver också idéer som bidrar till att uppnå bättre tillgänglighet till gemensam lägesinformation.

Olika webportallösningar kan vara användbara för att presentera läges-information. Boury-Brisset[86] beskriver i en artikel en portal avsedd att demonstrera hur militära beslutsfattare och operatörer skall kunna samarbeta mer effektivt över organisationsgränser, genom att utnyttja webbaserade tekniker som ger möjlighet att dela och hantera information och kunskap.

Att kunna uppnå interoperabilitet på den lägsta, tekniska nivån är allt annat än trivialt, men är ändå görbart genom att definiera protokoll och specifikationer för hur kommunikationen ska ske. För att hantera denna typ av teknisk inter-operabilitet har olika överenskommelser om NATO-standarder (så kallade STANAGs) tagits fram. I Essendorfer[87] et al beskrivs en dataserver som möjliggör distribuerad och sökbar information som kan delas mellan olika NATO-organisationer.

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[85] Se t. ex. J Brynielsson och P Svenson, ”FoU-översikt till stöd för gemensam lägesinformationsdatabas (GLID)”, FOI Memo 2980, 2009.

[86] A-C Boury-Brisset. A Collaborative Command Portal Environment in Support of Crisis and Emergency Situations. NATO RTO IST-RSY-086 on C3I for Crisis, Emergency and Consequence Management, Bukarest, Maj 2009.

[87] B Essendorfer och W Mueller. Interoperable Sharing of Data with the Coalition Shared Data (CSD) Server. NATO RTO IST-RSY-086 on C3I for Crisis, Emergency and Consequence Management, Bukarest, Maj 2009.

Ett ännu större problem är dock hur man ska kunna hantera kognitiva och kulturella skillnader mellan organisationer och förband. I ett EU-projekt vid namn Oasis har försök gjorts att ta fram ett ramverk baserat på öppen och flexibel arkitektur som ska utgöra grunden för ett europeiskt katastrof-hanteringssystem. Cullen[88] et al beskriver i sin artikel hur samarbete mellan olika blåljusmyndigheter skulle kunna fungera med Oasis som grund. Ett konkret problem med denna typ av interoperabla system är hur säkerheten upprätthålls så att användare endast kommer åt den information de har behörighet att ta del av, varför lösningar även för detta diskuteras.

För att kunna utbyta gemensamt förståelig lägesinformation på högre nivå än "bits and bytes", dvs förstå semantiken på samma sätt krävs ofta någon form av samordning på ontologisk nivå, såsom att kunna hantera information definierad utifrån en organisations ontologi som skall skickas över till en annan organisa-tion och där förstås på samma sätt, d.v.s. uppnå så kallad semantisk inter-operabilitet. Problemet berörs tidigare i denna rapports kapitel om ontoligistödd fusion eftersom det är viktigt för att alls kunna utföra korrekt fusion och inte s.a.s. fusionera "äpplen och päron". Inom NATO är området mycket viktigt[89], och det bör nämnas att Sverige genom FOI är aktiva inom området, men eftersom aktiviteter där FOI varit inblandade inte är avsedda att omnämnas närmare i denna rapport går vi här inte in närmare på det.

Nedan refereras till sist några artiklar inom sensorfusionsområdet, samt idéer och existerande system för förenklad anslutning, dataavtappning och styrning av sensorer i nätverk.

Wright[90] et al beskriver ganska detaljerat en mellanlagers "middleware" infrastruktur "the ITA Sensor Fabric" som utgör ett nätverk av löst sammankopplade sensorer, C2 (lednings) centraler och användare. Det erbjuder i "SOA-anda" funktioner för plug-and-play sensorer och mjukvara (för exempelvis fusion), sensorupptäckt –identifiering och styrning. Simuleringssystem påstås enkelt kunna samspela med infrastrukturen. Publicering och prenumeration av sensorresurser sköts via mäklartjänster, och såväl direktanvändare, lednings-system som mjukvaruagenter (såsom en fusionsnod) kan använda dessa. Ingen direktkontakt med sensorerna sker, allt går via mäklarna. Det hela är mycket

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[88] A Cullen, S Barker, S Case, T Rye, B Rossow och E Wilkinson. The Oasis Approach to Civil/Military Information Sharing for Disaster and Emergency Management. NATO RTO IST-RSY-086 on C3I for Crisis, Emergency and Consequence Management, Bukarest, Maj 2009.

[89] Se exempelvis slutrapport från arbetsgrupp NATO RTO IST-075 (aktiv 2007 – 2009) och FOI-R—2846—SE . http://reproserver.foi.se/kordajobb/foir2846.pdf

[90] J Wright, C Gibson, F Bergamaschi, K Marcus, R Pressley, G Verma och G Whipps. A dynamic infrastructure for interconnecting disparate ISR/ISTAR assets (the ITA Sensor Fabric). Fusion 2009.

intressant som idé på hur man försöker komma från stuprörslösningar och standardisera åtkomsten till, och hanteringen av, heterogena sensorresurser och fusionsfunktioner för att ge för fler användare bättre möjligheter till nyttjande av dem, och för att dela informationen från dem.

Barngrover[91] et al beskriver ett lågnivåsystem där disparat sensorinformation från radar, kameror (bl.a. burna av semiautonoma UGV:er, d.v.s. markgående obemannade farkoster) samt marksensorer fusioneras för att förse ledningsplatser med information så UGVerna kan styras effektivt. Då vapen avfyras av motståndaren detekteras detta automatiskt och förs in i ledningssystemet. Egna vapen på UGV:erna kan från detta styras mot motståndaren. I en relaterad artikel[92] beskriver de marksensorer (akustiska, seismiska och magnetiska) som används för inträngningsupptäckt. Publikationen behandlar upptäcktssannolikhet, risk för falsklarm när inget finns där och risk för inget larm när något faktiskt finns där. Dessa ökar då sensorerna placeras i bullriga områden (flygfält etc), men med enkel filtreringsteknik kunde de kraftigt förbättras.

Vid en workshop vid Fraunhoferinstitutet i Euskirchen i Tyskland i maj 2010 beskrevs ett par intressanta system där principer för sensorhantering och -fusion i ett SOA perspektiv berördes. Det första systemet beskrevs av Kym Watson[93] från OGC: "Using standards of the Open Geospatial Consortium to support data and information fusion". Standarderna syftar till att underlätta utbytet av sensor-information över organisationsgränser. Sensor Web Enablement (SWE) presenterades, en arkitektur för sensoråtkomst, planering, hantering av observationer m.m. över Internet, baserad på öppna standarder. Fusions-algoritmer kan bl.a. packas som tjänster. Tjänsten Sensor Planning Service (SPS) presenterades. I SWE ingår även andra komponenter såsom Sensor Model Language (SensorML) med vilket en sensor kan publicera information om sin status. Man har bl.a. implementerat en "Fusion SOS/SPS Server" på plattformen "Information Management System Web Genesis". Vidare referenser till OGC's arbete inom området finns bl.a. i OGC Fusion Standards Study Engineering Report (OGC 09-138) från mars 2010[94].

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[91] C M Barngrover, R T Laird, T A Kramer, J R Cruickshanks och S H Cutler. Data Fusion Engine (DFE) for the Force Protection Joint Experiment (FPJE). Proc. SPIE, Vol. 7345, 73450D (2009).

[92] C.M Barngrover, R T Laird, T A Kramer, J R Cruickshanks och S H Cutler. Force Protection Joint Experiment (FPJE) Battlefield Anti-Intrusion System (BAIS) sensors data analysis and filtering metrics Proc. SPIE, Vol. 7345, 73450I (2009).

[93] K Watson (OGC). Using standards of the Open Geospatial Consortium to support data and information fusion. Föredrag vid trilateral workshop SWE-GER-NLD i Euskirchen, Tyskland, maj 2010.

[94] Se http://portal.opengeospatial.org/files/?artifact_id=36177 (weblänk giltig november 2010).,

Det andra systemet beskrevs av Sandro Leuchter[95] från Fraunhofer IOSB "Semantic System-of-Systems Engineering for Creating ISR Networks". Här beskrevs "German Smart Sensor Web", en prototyp till integrationsinfrastruktur för nätverkande sensorer inom tyska försvarsmakten. Tid till skarpt system angavs till ca 4 år. Den innehåller även viss fuktionalitet för att genom NLP (Natural Language Processing) extrahera lägesinformation från mänskligt genererade meddelanden (Recce e.t.c). För detta används textanalysmjukvaran GATE. Infrastrukturen har en mellanlager baserat på agentteknologi, ontologier, semantiska representationer av sensordata och annan ISR relevant information.

I takt med att antalet sensorer i världen ökar alltmer så blir utmaningen att hitta relevant information i alla dataströmmar allt större. I ett nätverksbaserat försvar ställs stora krav på fungerande sensorstyrning, då ett uppdrags genomförande kan kräva tillgång till flera olika heterogena sensorer, och där olika uppdrag kan göra anspråk på en och samma sensor. För att lösa denna typ av problematik föreslår Avasarala[96] et al en marknadsbaserad resursstyrning, där konsumenter av sensorresurser ger bud på resurserna som på en auktion, och där högstbjudande får tillgång till resursen. Detta är en form av decentraliserad styrning, där sensorer allokeras distribuerat istället för i en enda central nod i nätverket.

En besläktad decentraliserad spelteoretisk lösning föreslås av Li[97] et al, där syftet är att styra sensorer för att optimera resursutnyttjandet samt kvaliteten på följningen av mål. För att uppnå detta föreslås en agentbaserad lösning, där en agent skapas för varje nytt mål, och där de olika agenterna förhandlar sinsemellan för att besluta hur sensorresurser ska fördelas. Den föreslagna metodiken har utvärderats med hjälp av simuleringar, där initiala resultat talar för att denna typ av lösningar fungerar väl.

Resursstyrningen måste även vara adaptiv och dynamisk, eftersom uppdrag snabbt kan ändras och för att sensorer i många typer av miljöer kan bli otillgängliga, förstöras eller tillkomma. Farahbod[98] et al har utvecklat en anpassningsbar arkitektur för resursstyrning som bygger på Dynamic Resource

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[95] Sandro Leuchter (Fraunhofer IOSB): "Semantic System-of-Systems Engineering for Creating ISR Networks". Föredrag vid trilateral workshop SWE-GER-NLD i Euskirchen, Tyskland, maj 2010. (Abstract saknas).

[96] V Avasarala, T Mullen och D Hall. A Market-based Approach to Sensor Management. Journal of Advances in Information Fusion, Vol. 4, Nr 1, Juni 2009, s. 52-71.

[97] X Li, G Chen, E Blasch, J Patrick, C Yang och I Kadar. Multi-sensor management for data fusion in target tracking. Proc. SPIE, Vol. 7336, 73360Y (2009).

[98] R Farahbod, U Glässer och A Khalili. A multi-layer network architecture for dynamic resource configuration and management of multiple mobile resources in maritime surveillance. Proc. SPIE, Vol. 7345, 734508 (2009).

Configuration & Management Architecture (DRCMA), vilken i sin tur bygger på användandet av tillståndsmaskiner.

Vi nämner här slutligen en artikel av Rabbat och Coates[99] där de anser att det enorma antalet sensorer som finns i många av världens städer i form av bland annat övervakningskameror bör kunna utnyttjas i kris- eller nödsituationer för att uppnå en bättre (gemensam) lägesförståelse. Att effektivt utnyttja ett sådant stort sensornätverk är dock långtifrån trivialt. I detta papper beskrivs viktiga problem i denna typ av nätverk, såsom resursallokering, decentraliserad följning av multipla objekt, samt anomalidetektion.

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[99] M Rabbat och M Coates. Fusion and Inference in Surveillance Networks. NATO RTO IST-RSY-086 on C3I for Crisis, Emergency and Consequence Management, Bukarest, Maj 2009.

12 Utvalda tidskriftsartiklar med abstract

12.1 Artiklar från International Journal of Information Fusion

Ordnat efter utgivningsmånad och sidnummer.

12.1.1 A blueprint for higher-level fusion systems

D A Lambert. Information Fusion Vol. 10, Nr. 1, Januari 2009, s. 6-24.

This paper contends that demands on the data fusion community are beginning to exceed its historical roots in sensor fusion, by requiring greater development of automated situation and impact assessments and more appropriate integration with humans engaged in fusion activity. The paper offers a seven building block blueprint for the design of higher-level fusion systems. The first building block involves a deconstruction of the JDL model to apply it beyond machine based fusion. The second addresses machine representation for automated situation and impact assessments, while the third examines machine reasoning for automated situation and impact assessments. The fourth building block then reconstructs a unified framework for automated object, situation and impact assessments so as to accommodate both of the previous building blocks and the traditional approach to sensor fusion. Distributed data fusion constitutes the subsequent building block. The automated presentation of automated situation and impact assessments serves as the sixth building block, before the issue of human involvement in higher-level fusion systems is canvassed. Existing implementations of the various building blocks are referenced rather than discussed in any detail. The aim of the paper is to expose the overarching framework for these higher-level fusion systems without recourse to their considerable underlying complexity.

12.1.2 An integrated approach to high-level information fusion

K Sycara, R Glinton, B Yu, J Giampapa, S Owens, M Lewis och LTC C Grindle. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s. 25-50.

In today's fast paced military operational environment, vast amounts of information must be sorted out and fused not only to allow commanders to make situation assessments, but also to support the generation of hypotheses about enemy force disposition and enemy intent. Current information fusion technology has the following two limitations. First, current approaches do not consider the battlefield context as a first class entity. In contrast, we consider situational context in terms of terrain analysis and inference. Second, there are no integrated and implemented models of the high-level fusion process. This paper describes the HiLIFE (High-Level Information Fusion Environment) computational framework for seamless integration of high levels of fusion (levels 2, 3 and 4). The crucial components of HiLIFE that we present in this paper are: (1) multi-sensor fusion algorithms and their performance results that operate in heterogeneous sensor networks to determine not only single targets but also force aggregates, (2) computational approaches for terrain-based analysis and inference that automatically

combine low-level terrain features (such as forested areas, rivers, etc.) and additional information, such as weather, and transforms them into high-level militarily relevant abstractions, such as NO-GO, SLOW-GO areas, avenues of approach, and engagement areas, (3) a model for inferring adversary intent by mapping sensor readings of opponent forces to possible opponent goals and actions, and (4) sensor management for positioning intelligence collection assets for further data acquisition. The HiLIFE framework closes the loop on information fusion by specifying how the different components can computationally work together in a coherent system. Furthermore, the framework is inspired by a military process, the Intelligence Preparation of the Battlefield, that grounds the framework in practice. HiLIFE is integrated with a distributed military simulation system, OTBSAF, and the RETSINA multi-agent infrastructure to provide agile and sophisticated reasoning. In addition, the paper presents validation results of the automated terrain analysis that were obtained through experiments using military intelligence Subject Matter Experts (SMEs).

12.1.3 Designing ontologies for higher level fusion

E G Little och G L Rogova. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s. 70-82.

The purpose of higher level fusion is to produce contextual understanding of the states of the environment and prediction of their impact in relation to specific goals of decision makers. One of the main challenges of designing higher level fusion processes is to provide a formal structure of domain-specific types of entities, attributes, situations, and the relations between them for reasoning about situations and threats. This paper presents an attempt at confronting this challenge by describing a process for building formal ontologies that combines a top–down philosophical perspective (from the most abstract levels to domain-specific levels) with a bottom-up application-based perspective (from domain-specific levels to the most abstract levels). The main focus of this paper is to provide a conceptual framework for formally capturing various sorts of complex relation-types, which can serve as a means for a more thorough decomposition of objects, attributes/properties, events, processes, and relations, necessary for higher level fusion processing.

12.1.4 Ontology-based situation awareness

M M Kokar, C J Matheus och Kenneth Baclawski. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s 83-98.

The notions of "situation" and "situation awareness" have been formulated by many authors in various contexts. In this paper, we present a formalization of situations that is compatible with the interpretation of situation awareness in terms of human awareness as well as the situation theory of Barwise and Devlin. The purpose of this paper is to capture the situation theory of Barwise in terms of an OWL ontology. This allows one to express situations in a commonly supported language with computer processable semantics. The paper provides a description of the classes and the properties in the ontology, and illustrates the formalization with some simple examples.

12.1.5 High level information fusion for tracking and projection of multistage cyber attacks

S J Yang, A Stotz, J Holsopple, M Sudit och M Kuhl. Information Fusion, Vol. 10, Nr. 1, Januari 2009, s. 107-121.

The use of computer networks has become a necessity for government, industry, and personal businesses. Protection and defense against cyber attacks on computer networks, however, are becoming inadequate as attackers become more sophisticated and as the networks and systems become more complex. Drawing analogies from other application domains, this paper introduces information fusion to provide situation awareness and threat prediction from massive volumes of sensed data. An in-depth discussion is provided to define fusion tasks for cyber defense. A novel cyber fusion system is proposed to address specifically the tracking and projection of multistage attacks. Critical assessments of the developed attack tracking and threat projection sub-components are provided with simulation results. This pioneering work elaborates the benefits, limitations, and future challenges of high level information fusion for cyber security.

12.1.6 Agent-based information fusion (Guest editorial)

S Das. Information Fusion, Vol. 11, Nr. 3, Juli 2010, s. 216-219.

Recent advances in intelligent agent research have culminated in various agent-based applications that autonomously perform a range of tasks on behalf of human operators. Examples of the kinds of tasks these applications perform include information filtering and retrieval, situation assessment and decision support and interface personalization. Each of these tasks requires some form of human-like intelligence that must be simulated and embedded within the implemented agent-based application. Expectations that agent technologies can provide insights into and solutions for complex problems are high in the industrial, military, and business fusion communities. Moreover, such expectations are also due to the agents' inherent capability of operating autonomously and communicating and coordinating with other agents in the environment. This makes them suitable for embedding in entities operating in hazardous and high-risk operational environments, including robots, Unmanned Air Vehicles, Unattended Ground Sensors, etc. A recent DoD-wide thrust on Network Centric Warfare (NCW) is by definition distributed in nature, where agents can potentially play a vital role in the areas of cooperation, coordination, brokering, negotiation and information filtering retrievalAutonomous intelligent agents can act on behalf of warfighters within an NCW environment to reduce their cognitive workload…………

12.1.7 Peer-to-peer coupled agent systems for distributed situation management

J F Buford, G Jakobson och L Lewis. Information Fusion, Vol. 11, Nr. 3, Juli 2010, s. 233-242.

Large scale situation management applications such as disaster recovery and network-centric battle management are characterized by distributed heterogeneous agent platforms with dynamic agent populations, highly variable network connectivity and bandwidth, and localized situation knowledge and event collection. We describe a new agent model and an integrated peer-to-peer architecture which addresses these requirements. We present an extension of the BDI agent model which allows it to be used in highly reactive applications. We describe the use of multi-hop peer-to-peer overlays which provides highly scalable coupling of distributed agent platforms. Finally, we describe a two-phase semantic discovery mechanism which serves as a basis for agents to share events and situations across the overlay.

12.1.8 Enhancements to high level data fusion using graph matching and state space search

K Sambhoos, R Nagib, M Sudit och A Stotz. Information Fusion, Vol. 11, Nr. 4, Oktober 2010, s. 351-364.

The intent of this paper is to show enhancements in Levels 2 and 3 fusion capabilities through a new class of models and algorithms in graph matching. The problem today is not often lack of data, but instead, lack of information and data overload. Graph matching algorithms help us solve this problem by identifying meaningful patterns in voluminous amounts of data to provide information. In this paper we investigate a classical graph matching technique for subgraph isomorphism. A complete implementation of a heuristic approach (since the problem under consideration is NP-Hard) using an inexact isomorphism technique has been used. The heuristic approach is called Truncated Search Tree algorithm (TruST), where the state space of the problem is constrained using breadth and depth control parameters. The breadth and depth control parameters are then studied using design of experiment based inferential statistics. Finally, a software implementation of the procedure has been completed.

12.2 Artiklar från Journal of Advances in Information Fusion (JAIF)

Ordnat efter utgivningsmånad.

12.2.1 Hierarchical Higher Level Data Fusion using Fuzzy Hamming and Hypercube Clustering

K Sambhoos, R Nagi, M Sudit och T Rickard. Journal of Advances in Information Fusion, Vol. 3, Nr 2, December 2008, s. 90-106.

The primary objective of this research is to show progression of Level 2/3 fusion of informational content to obtain a framework for hierarchical high level decision making process. The goal of this paper is to develop an algorithm to solve the impending problem of situation assessment. In [*intern ref*], an inexact graph matching technique called Truncated Search Tree algorithm (TruST) has been developed. The inexact graph matching is used to identify meaningful patterns in voluminous amounts of data. This heuristic is based on the popular branch-and-bound technique with constraints on breadth and depth. To reduce the dimensionality of the matches found, the results are grouped using a clustering algorithm. A novel Hypercube distance measure is used in clustering the matched subgraphs. This measure is then compared with a relatively new Fuzzy Hamming distance measure. To identify the important nodes and links in the data graph, the clustered subgraphs are then fused together and the neighborhood structure is explored.

12.2.2 A Market-based Approach to Sensor Management

V Avasarala, T Mullen och D Hall. Journal of Advances in Information Fusion, Vol. 4, Nr 1, Juni 2009, s. 52-71.

Given the explosion in number and types of sensor nodes, the next generation of sensor management systems must focus on identifying and acquiring *valuable* information from this

potential flood of sensor data. Thus an emerging problem is deciding what to produce, where, for whom, and when. Identifying and making tradeoffs involved in information production is a difficult problem that market-based systems can "solve" by allowing user values, or utilities, to drive the selection process. Essentially this transforms the traditional "data driven" approach (in which multiple sensors and information sources are used, with a focus on how to process the collected data) to a user-centered approach in which one or more users treat the information collection and distribution system as a market and vie to acquire goods and services (e.g., information collection, processing resources and network bandwidth). We describe our market-based approach to sensor management, and compare our prototype system to an information-theoretic system in a multisensor, multi-user simulation with promising results. This research is motivated in part, by rapid technology advances in network technology and in sensing. These advances allow near universal instrumentation and sensing with worldwide distribution. However while advances in service-oriented architectures and web-based tools have created "the plumbing" for data distribution and access, improvements in optimization of these distributed resources for effective decision making have lagged behind the collection and distribution advances.

12.3 Artiklar från Journal of Decision Support Systems

Ordnat efter utgivningsmånad.

12.3.1 Using text mining and sentiment analysis for online forums hotspot detection and forecast

N Li och D D Wu. Decision Support Systems, Vol. 48, Nr. 2, Januari 2010, s. 354-368.

Text sentiment analysis, also referred to as emotional polarity computation, has become a flourishing frontier in the text mining community. This paper studies online forums hotspot detection and forecast using sentiment analysis and text mining approaches. First, we create an algorithm to automatically analyze the emotional polarity of a text and to obtain a value for each piece of text. Second, this algorithm is combined with K-means clustering and support vector machine (SVM) to develop unsupervised text mining approach. We use the proposed text mining approach to group the forums into various clusters, with the center of each representing a hotspot forum within the current time span. The data sets used in our empirical studies are acquired and formatted from Sina sports forums, which spans a range of 31 different topic forums and 220,053 posts. Experimental results demonstrate that SVM forecasting achieves highly consistent results with K-means clustering. The top 10 hotspot forums listed by SVM forecasting resembles 80% of K-means clustering results. Both SVM and K-means achieve the same results for the top 4 hotspot forums of the year.

12.3.2 Visualizing social network concepts

B Zhu, S Watts, and H Chen. Decision Support Systems, Vol. 49, Nr. 2, Maj 2010, s. 151-161.

Social network concepts are invaluable for understanding the social network phenomena, but they are difficult to comprehend without computerized visualization. However, most existing network visualization techniques provide limited support for the comprehension of network concepts. This research proposes an approach called concept visualization to facilitate the

understanding of social network concepts. The paper describes an implementation of the approach. Results from a controlled laboratory experiment indicate that, compared with the benchmark system, the NetVizer system facilitated better understanding of the concepts of betweenness centrality, gatekeepers of subgroups, and structural similarity. It also supported a faster comprehension of subgroup identification.

12.3.3 Modeling challenges with influence diagrams: Constructing probability and utility models

Influence diagrams have become a popular tool for representing and solving complex decision-making problems under uncertainty. In this paper, we focus on the task of building probability models from expert knowledge, and also on the challenging and less known task of constructing utility models in influence diagrams. Our goal is to review the state of the art and list some challenges. Similarly to probability models, which are embedded in influence diagrams as a Bayesian network, preferential/utility independence conditions can be used to factor the joint utility function into small factors and reduce the number of parameters needed to fully define the joint function. A number of graphical models have been recently proposed to factor the joint utility function, including the generalized additive independence networks, ceteris paribus networks, utility ceteris paribus networks, expected utility networks, and utility diagrams. Similarly to probability models, utility models can also be engineered from a domain expert or induced from data.

12.3.4 Knowledge-based scenario management — Process and Support

Scenario planning is a widely accepted management process for decision support activities. Though conventional decision support systems provide a strong database, modeling and visualization capabilities for the decision maker, they do not explicitly support scenario management. We propose an integrated life cycle approach for knowledge-based scenario-driven decision support incorporating three interrelated frameworks at different abstraction levels to support this process. The macro-level knowledge-based framework guides the Meso-level Scenario-driven framework, and these two in turn guide and inform the micro-level process-oriented framework. We develop a domain independent, component-based, and layered architecture to support the scenario management process and framework. The framework and architecture are realized through a concrete prototype.

13 Utvalda konferensartiklar med abstract

13.1 Artiklar från International Conference on Information Fusion 2009 (Fusion 2009)

Ordnat alfabetiskt efter titel.

13.1.1 Acoustic vehicle classification by fusing with semantic annotation

B Guo, M Nixon och T Damarla.

Current research on acoustic vehicle classification has been generally aimed at utilizing various feature extraction methods and pattern recognition techniques. Previous research in gait biometrics has shown that domain knowledge or semantic enrichment can assist in improving the classification accuracy. In this paper, we address the problem of semantic enrichment by learning the semantic attributes from the training set, and then formalize the domain knowledge by using ontologies. We first consider a simple data ontology, and discuss how to use it for classification. Next we propose a scheme, which uses a semantic attribute to mediate information fusion for acoustic vehicle classification. To assess the proposed approaches, experiments are carried out based on a data set containing acoustic signals from five types of vehicles. Results indicate that whether the above semantic enrichment can lead to improvement depends on the accuracy of semantic annotation. Among the two enrichment schemes, semantically mediated information fusion achieves less significant improvement, but is insensitive to the annotation error.

13.1.2 A Dempster-Shafer theoretic conditional approach to evidence updating for fusion of hard and soft data

K Premaratne, M Murthi, J Zhang, M Scheutz och P Bauer.

Fusion of hard data with soft data is an issue that has attracted recent attention. An effective fusion strategy requires an analytical framework that can capture the uncertainty inherent in hard and soft data. For instance, computational linguistic parsing of text-based data generates logical propositions that inherently possess significant semantic ambiguity. An effective fusion framework must exploit the respective advantages of hard and soft data while mitigating their particular weaknesses. In this paper, we describe a Dempster-Shafer theoretic approach to hard and soft data fusion that relies upon the novel conditional approach to updating. The conditional approach engenders a more flexible method that allows for tuning and adapting update strategies. When computational complexity concerns are taken into account, it also provides guidance on how evidence could be ordered for updating. This has important implications in working with models that convert propositional logic statements from text into Dempster-Shafer theoretic form.

13.1.3 A dynamic infrastructure for interconnecting disparate ISR/ISTAR assets (the ITA sensor fabric)

J Wright, C Gibson, F Bergamaschi, K Marcus, R Pressley, G Verma och G Whipps.

Modern ISR/ISTAR networks comprise a very diverse and disparate set of asset types and networking technologies, which provide a unique set of challenges in the areas of sensor identification, classification, interoperability and sensor data sharing, dissemination and consumability. This paper presents the ITA sensor fabric, developed as part of the international technology alliance (ITA) in network and information science, a middleware infrastructure that addresses these challenges by providing unified/universal policy controlled access to, and management of, ISR/ISTAR networks. The ITA sensor fabric spans the network from command and control, through forward operating bases, and out to mobile forces and fielded (both mobile and/or fixed) sensors in the area of operations. This paper also presents a use case scenario developed in partnership with the U.S. Army Research Laboratory (ARL) and deployed in ARL's Wireless Emulation Laboratory (WEL), that demonstrates the ITA Sensor Fabric applicability to coalition operations.

13.1.4 A multi-disciplinary approach to high level fusion in predictive situational awareness

P C Costa, K-C Chang, K Laskey och R Carvalho.

The change of focus in modern warfare from individual platforms to the network has caused a concomitant shift in supporting concepts and technologies. Greater emphasis is placed on interoperability and composeability. New technologies such as SOA and semantically aware systems have come into the spotlight. This paper argues that just as the problem space demands interoperability of diverse technologies, so must the solution space. In other words, not only are new approaches needed, but they must also come together as a seamlessly interoperable technological tool set. This can be accomplished only via a consistent multi-disciplinary approach. In this paper, we present some of the major requirements of today's predictive situation awareness systems (PSAW), propose our approach as a coordinated mix between state-of-the-art research efforts, and present the architecture for enabling our approach.

13.1.5 Analytic Network Process for model elicitation in nation-building simulations

Y Zhang, R Nagi och M Sudit.

Discrete-event simulation models are the current main tools for nation-building analysis due to the complexity of the problem. However, it is difficult to study the input-output relations in these models because of the numerous parameters as well as the complicated model structure. Model elicitation can be considered as an approximate study of the significant effects of the model without spending excessive time in multiple replications of discrete event simulation. In this paper, Analytic Network Process (ANP) is applied to model elicitation in large-scale nation-building models. It can be used to study the factor significance and the inter-influence among different kinds of factors. This new approach is strictly based on the quantitative analysis instead of the expert knowledge, which greatly improves the traditional ANP method that uses possibly conflicting human expertise. The numeric results show that this

methodology provides good solutions at significantly reduced computational time compared with traditional discrete-event simulations.

13.1.6 An application of DSmT in ontology-based fusion systems

K Krenc och A Kawalec.

The aim of this paper is to propose an ontology framework for preselected sensors due to the sensor networks needs, regarding a specific task, such as the targets threat recognition. The problem will be solved methodologically, taking into account particularly non-deterministic nature of functions assigning the concept and the relation sets into the concept and relation lexicon sets respectively and vice versa. This may effectively enhance the efficiency of the information fusion performed in sensor networks.

13.1.7 An ensemble approach for increased anomaly detection performance in video surveillance data

C Brax, L Niklasson och R Laxhammar.

The increased societal need for surveillance and the decrease in cost of sensors have led to a number of new challenges. The problem is not to collect data but to use it effectively for decision support. Manual interpretation of huge amounts of data in real-time is not feasible; the operator of a surveillance system needs support to analyze and understand all incoming data. In this paper an approach to intelligent video surveillance is presented, with emphasis on finding behavioural anomalies. Two different anomaly detection methods are compared and combined. The results show that it is possible to best increase the total detection performance by combining two different anomaly detectors rather than employing them independently.

13.1.8 An information fusion framework for threat assessment

J Beaver, R Kerekes och J Treadwell.

Modern enterprises are becoming increasingly sensitive to the potential destructive power of small groups or individuals with malicious intent. In response, significant investments are being made in developing a means to assess the likelihood of certain threats to their enterprises. Threat assessment needs are typically focused in very specific application areas where current processes rely heavily on human analysis to both combine any available data and draw conclusions about the probability of a threat. A generic approach to threat assessment is proposed, including a threat taxonomy and decision-level information fusion framework, that provides a computational means for merging multi-modal data for the purpose of assessing the presence of a threat. The framework is designed for flexibility, and intentionally accounts for the accuracy of each data source, given the environmental conditions, in order to manage the uncertainty associated with any acquired data. The taxonomy and information fusion framework is described, and discussed in the context of real-world applications such as shipping container security and cyber security.

13.1.9 Anomaly detection in sea traffic - a comparison of the Gaussian Mixture Model and the Kernel Density Estimator

R Laxhammar, G Falkman och E Sviestins.

This paper presents a first attempt to evaluate two previously proposed methods for statistical anomaly detection in sea traffic, namely the Gaussian Mixture Model (GMM) and the adaptive Kernel Density Estimator (KDE). A novel performance measure related to anomaly detection, together with an intermediate performance measure related to normalcy modeling, are proposed and evaluated using recorded AIS data of vessel traffic and simulated anomalous trajectories. The normalcy modelling evaluation indicates that KDE more accurately captures finer details of normal data. Yet, results from anomaly detection show no significant difference between the two techniques and the performance of both is considered suboptimal. Part of the explanation is that the methods are based on a rather artificial division of data into geographical cells. The paper therefore discusses other clustering approaches based on more informed features of data and more background knowledge regarding the structure and natural classes of the data.

13.1.10 Building principles for a quality of information specification for sensor information

C Bisdikian, L Kaplan, M Srivastava, D Thornley, D Verma och R Young.

In the highly heterogeneous environments of coalition operations, sharing sensor originated information with desired quality characteristics is key to the effective execution of coalition tasks. A characterization of the quality of information (QoI) is useful in many contexts and can be invaluable in making decisions such as trusting, managing, and using information in particular applications. However, the manner of representing the QoI is highly application-dependent. This leads to divergent QoI characterizations and manifestations hampering the effective and streamlined execution of coalition tasks. An application-agnostic QoI specification can provide consistency in the representation of information and its quality, and enable QoI-aware determinations across many different applications. In this paper, an application-agnostic QoI model which can be readily customized to the needs of specific applications is presented. Object-oriented modelling principles are leveraged to attain a QoI model that can be used in many different contexts.

13.1.11 Context-sensitive data fusion using structural equation modeling

A Steinberg.

Context is used in data fusion - and in inferencing in general - to provide expectations and to constrain processing. It also is used to infer or refine desired information ("problem variables") on the basis of other available information (exogenous "context variables"). Context is used in refining data alignment and association as well as in target and situation state estimation. Relevant contexts are often not self-evident, but must be discovered or selected as a means to problem-solving. Therefore, context exploitation involves an integration of data fusion with planning and control functions. Structural Equation Modeling techniques are used to evaluate dependencies between latent and observed problem and context variables. Discovering and selecting useful context variables is an abductive data fusion/ management problem that can be characterized in a utility/ uncertainty framework. An adaptive evidence-accrual inference

method - originally developed for Scene Understanding - is presented, whereby context variables are selected on the basis of (a) their utility in refining explicit problem variables, (b) the probability of evaluating these variables to within a given accuracy, given candidate system actions (data collection, mining or processing), and (c) the cost of such actions.

13.1.12 Decentralised data fusion: A graphical model approach

A Makarenko och A Brooks.

This paper proposes the use of graphical models to describe decentralised data fusion systems. The task of decentralised data fusion is considered as a specific instance of the general distributed inference problem in which there is a single common state of interest which is (partially) observed by a number of sensor platforms. Our objective is to model and solve this problem using standard graphical model techniques. Two options for modeling the problem are considered. The model based on distributed variable cliques is found superior to a graphical model with cloned variables. The model and the messages arising through inference are compared with the well-known Channel Filter algorithm. Our approach to inference is to apply a distributed version of the Junction Tree algorithm developed by Paskin and Guestrin. The algorithms were validated in a series of simulated tracking problems.

13.1.13 Dempster-Shafer Theory: Combination of information using contextual knowledge

M C Florea och E Bossé.

The aim of this paper is to investigate how to improve the process of information combination, using the Dempster-Shafer theory (DST). In presence of an overload of information and an unknown environment, the reliability of the sources of information or the sensors is usually unknown and thus cannot be used to refine the fusion process. In a previous paper, the authors have investigated different techniques to evaluate contextual knowledge from a set of mass functions (membership of a BPA to a set of BPAs, relative reliabilities of BPAs, credibility degrees, etc.). The purpose of this paper is to investigate how to use the contextual knowledge in order to improve the fusion process.

13.1.14 Evaluation of a workshop to capture knowledge from subject matter experts in maritime surveillance

J van Laere och M Nilsson.

This paper reports on a brainstorming workshop with subject matter experts that aimed at identifying potential anomalies for world wide maritime surveillance. An extensive description of the workshop process and output is presented. The evaluation consists of two parts. First, the output of the workshop is compared with the output of a similar workshop as presented in Roy [1]. Secondly, the methodological differences between capturing know-how of subject matter experts in a workshop versus observing daily work of operators, as applied in Nilsson et al [2], is discussed. The conclusions are that brainstorming workshops and field studies should be combined to compensate for their weaknesses. Also, the outcomes of both methods heavily depend on the selection of operators to be observed, respectively the selection of subject matter experts invited. A final recommendation is that multiple studies and workshops are needed until no 'new' anomalies are identified.

13.1.15 Estimation of adversarial social networks by fusion of information from a wide range of sources

J Josephson, J Eckroth och T Miller.

A data structure is described that serves to define a target structure for estimating social networks. It represents who knows whom, the strength and polarity of associations, and levels of confidence that linked individuals are actually personally acquainted. This network, which represents social structure, is embedded in a more inclusive network structure that also represents vehicles, places and organizations. This broader structure can be used to accumulate information to enable automated inferencing to assist human processing in estimating the social network of interest. How portions of this inferencing can be done is briefly described, and a scenario is given that illustrates the use of this kind of fused information to make a decision. We also review a range of hard and soft information sources with emerging value for estimating adversarial social networks, and describe how these sources can be used for the purpose.

13.1.16 Foundations for system implementation for a centralised intelligence fusion framework for emergency services

D Vincen, D Stampouli och G Powell.

There is an identified need for software to provide centralised command and control, information sharing, and support intelligence analysis tasks. In this paper we report on ongoing development of a centralised intelligence fusion framework to provide data and information fusion for interoperability of emergency services. In particular, the design, and specification of such a complex system is particular challenging, so this paper is focusing on the issues relating to system implementation, such as requirements and system architecture concepts. This paper aims to discuss technological foundations, and review some of available technologies which are currently combined as an initial implementation attempt. By using the described technologies for definition of hard and soft data through probabilistic enhanced ontologies and enriching service interfaces with semantic attributes in a service oriented architecture the situation and thread assessment are addressed for emergency services.

13.1.17 Generalized Chernoff fusion approximation for practical distributed data fusion

W Farrell och C Ganesh.

This paper advances research in practical distributed data fusion with an emphasis on the generalized fusion of probability density functions in the presence of unknown correlations. Specifically, the proposed algorithm addresses fusion of any finite number of probability density functions in a distributed tracking environment where "rumor propagation" and statistical correlations may be present. This "rumor propagation" arises in real-world tactical military applications where distributed fusion nodes have dynamic and multi-cyclic data flows. In addition, interoperability requirements with legacy systems preclude control over pre-processing of data fusion inputs to ensure statistical independence or modify legacy systems with pedigree tagging techniques. Leveraging the well-known covariance intersection algorithm, its generalization, and previously developed approximations to covariance intersection, a computationally simple approximation for the generalized fusion of any number of probability density functions is presented as the novel result of this paper. The derivation of

this algorithm and numerical examples illustrate that the proposed approach enables practical fusion of generalized (non-Gaussian) observations in an ad-hoc distributed fusion network without the need for pedigree tagging.

13.1.18 Hierarchical information fusion for human upper limb motion capture

Z Zhang, H Zhipei och J Wu.

Motion capture serves as a key technology in a wide spectrum of applications, including interactive game and learning, animation, film special effects, health-care and navigation. The existing human motion capture techniques, which use structured multiple high resolution cameras in the dedicated studio, are complicated and expensive. As rapid development of micro inertial sensors-on-chip, ubiquitous, real-time, and low cost human motion capture system using micro-inertial-sensors (MMocap) becomes possible. This paper presents a novel motion estimation algorithm by hierarchical fusion of sensor data and constraints of human dynamic model for human upper limb motion capture. Our method represents orientations of upper limb segments in quaternion, which is computationally effective and able to avoid singularity problem. To address the nonlinear human body segment motion, a particle filter is proposed to fuse 3D accelerometer and 3D micro-gyroscope sensor data to estimate upper limb motion recursively. Drift is the most challenging issue in motion estimation using inertial sensors. We present a novel solution by modeling the geometrical constraints in elbow joint and fuse these constraints to the particle filter process to compensate drift and improve the estimation accuracy. The experimental results have shown the feasibility and effectiveness of the proposed motion capture and analysis algorithm.

13.1.19 How certain is certain? Evaluation of uncertainty in the fusion of information derived from diverse sources

K Rein och U Schade.

Todays asymmetric military operations, often involve multiple partners, including the armed forces of allied nations, relief agencies and other organizations. Background information is culled from many different sources, including humans, sensors, and robots. Timely evaluation of intelligence with background information is necessary for effective operations, but its sheer volume poses a challenge. Formulating reports involving actions, events and status in a standardized formal language such as battle management language (BML) provides a basis for automatic fusion of individual pieces of information into complex, identifiable patterns of behavior. However, since sources of information are seldom completely reliable, the fusion of data is inherently unreliable. Evaluating the degree of reliability of the information will support effective decision making. In this paper we examine issues involved in the evaluation of the uncertainty in the fusion of information from diverse sources and propose a methodology for evaluation of this uncertainty.

13.1.20 Implication of culture: User roles in information fusion for enhanced situational understanding

E Blasch, P Valin, E Bossé, M Nilsson, J van Laere och E Shahbazian.

Information fusion coordinates large-volume data processing machines to address user needs. Users expect a situational picture to extend their ability of sensing events, movements, and activities. Typically, data is collected and processed for object location (e.g. target identification) and movement (e.g. tracking); however, high-level reasoning or situational understanding depends on the spatial, cultural, and political effects. In this paper, we explore opportunities where information fusion can aid in the selection and processing of the data for enhanced tacit knowledge understanding by (1) display fusion for data presentation (e.g. cultural segmentation), (2) interactive fusion to allow the user to inject a priori knowledge (e.g. cultural values), and (3) associated metrics of predictive capabilities (e.g. cultural networks). In a simple scenario for target identification with deception, cultural information impacts on situational understanding is demonstrated using the technology-emotion-culture-knowledge (TECK) attributes of the observe-orient-decide-act (OODA) model.

13.1.21 Incorporating the human analyst into the data fusion process by modeling situation awareness using fuzzy cognitive maps

R Jones, E Connors och M Endsley.

Current data fusion models lack the capability of fully supporting the cognitive processes of the human analyst. The data fusion community has expressed a need to better incorporate users within their models. The purpose of this paper is to describe how to use fuzzy logic to develop a data fusion model that supports situation awareness (SA). Developing this model based on the formal representation of the analyst provided by the goal-directed task analysis (GDTA) methodology advances current data fusion models because it provides valuable insight on how to effectively support human cognition within the data fusion process.

13.1.22 Incremental graph matching for Situation Awareness

A Stotz, R Nagi och M Sudit.

In this paper, an incremental subgraph matching problem is introduced as an enhancement to a batched inexact subgraph isomorphism for situation assessment in higher levels of data fusion. The procedure is shown to be a bounded incremental algorithm, meaning that its runtime is a function of the size of the change in the data graph. Solution quality results are shown to be equal to that of TruST with large improvements in runtime for graphs even in the size range of thousands of nodes. This new enhancement allows subgraph isomorphism procedures to be applied to new types of fusion problems.

13.1.23 Information evaluation in fusion using information correlation

J Besombes, V Nimier och L Cholvy.

This paper first analyses NATO recommendations in information evaluation for intelligence. Then it presents a definition of information evaluation which is based on the notion of correlation between two pieces of information. It also shows how an ontology can be used to estimate correlations. Finally, it presents a general process which computes information evaluation according to this definition and it shows that this process agrees NATO recommendations.

13.1.24 Intention recognition for partial-order plans using Dynamic Bayesian Networks

P Krauthausen och U Hanebeck.

In this paper, a novel probabilistic approach to intention recognition for partial-order plans is proposed. The key idea is to exploit independences between subplans to substantially reduce the state space sizes in the compiled dynamic Bayesian networks. This makes inference more efficient. The main contributions are the computationally exploitable definition of subplan structures, the introduction of a novel layered intention model and a dynamic Bayesian network representation with an inference mechanism that exploits consecutive and concurrent subplans' independences. The presented approach reduces the state space to the order of the most complex subplan and requires only minor changes in the standard inference mechanism. The practicability of this approach is demonstrated by recognizing the process of shelf-assembly.

13.1.25 Joint threat assessment with asset profiling and entity Bayes net

T Lampinen, J Ropponen och T Laitinen.

The information load in a command and control task is enormous and is only aggravated in a joint battlespace. There is a constant need for the hierarchical processing of basic sensor data into higher level situation awareness. The purpose of our research project is to enhance situation awareness and decision support within joint C2 systems through a profound hierarchical range of auto-generated real-time and knowledge-based information. In the project, coordinated with the Finnish Air Force HQ, we have implemented and developed several situation and threat assessment (STA) and profiling algorithms within our STA testbed (STATB) with realistic scale scenario simulations. The system consists of algorithms in JDL levels 1-3 for joint situations with airborne, ground, and naval aspects. The entity Bayes nets perform the threat assessment between the adversary forces and friendly assets. Results from the system show that these concepts will provide improved situation awareness and decision support.

13.1.26 Mixed initiative soft data fusion associate

N Belov och P Gerken.

We present a mixed-initiative data fusion associate that incorporates an analyst into a dynamic, soft fusion and decision-making process. We describe how the mixed-initiative associate integrates with two existing Lockheed Martin Advanced Technology Laboratories' (ATL) systems: a spoken language reporting system and a dynamic human network persistence system, to provide a more accurate human network from the collection of human-generated reports. We provide a scenario demonstrating the use of the mixed-initiative fusion associate.

13.1.27 Ontological representation of context knowledge for visual data fusion

J Gomez-Romero, M Patricio, J Garcia Herrero och J Molina.

Context knowledge is essential to achieve successful information fusion, especially at high JDL levels. Context can be used to interpret the perceived situation, which is required for accurate assessment. Both types of knowledge, contextual and perceptual, can be represented with formal languages such as ontologies, which support the creation of readable representations and reasoning with them. In this paper, we present an ontology-based model compliant with JDL to represent knowledge in cognitive visual data fusion systems. We depict the use of the model with an example on surveillance. We show that such a model promotes system extensibility and facilitates the incorporation of humans in the fusion loop.

13.1.28 Signature-based activity detection based on Bayesian networks acquired from expert knowledge

F Fooladvandi och C Brax.

The maritime industry is experiencing one of its longest and fastest periods of growth. Hence, the global maritime surveillance capacity is in a great need of growth as well. The detection of vessel activity is an important objective of the civil security domain. Detecting vessel activity may become problematic if audit data is uncertain. This paper aims to investigate if Bayesian networks acquired from expert knowledge can detect activities with a signature-based detection approach. For this, a maritime pilot-boat scenario has been identified with a domain expert. Each of the scenario's activities has been divided up into signatures where each signature relates to a specific Bayesian network information node. The signatures were implemented to find evidences for the Bayesian network information nodes. AIS-data with real world observations have been used for testing, which have shown that it is possible to detect the maritime pilot-boat scenario based on the taken approach.

13.1.29 Situation assessment for a centralised intelligence fusion framework for emergency services

D Stampouli och D Vincen.

There is an identified need for systems to combine information from hard (electronic) and soft (human) sensors. In this paper we report an ongoing development of a centralised framework to provide data and information fusion for interoperability of emergency services. Issues relating to situation and threat assessment are discussed and fusion processes are suggested. Examples of how these processes can be applied to several police scenarios are given. Uncertainty grading of source is also examined and initial implementation attempts are presented.

13.1.30 Soft data analysis within a decision support system

C Laudy och B Goujon.

This paper presents a work achieved within a decision support system. The aim is to support an operator in his/her task of analyzing soft data to monitor and anticipate a geopolitical crisis. The incoming data is filtered and analyzed so as to retain only the relevant events. Therefore, the system extracts the relevant events from the incoming soft data and produces synthetic descriptions of these events. The approach is divided into three steps. First the domain of interest is modeled with an ontology. It describes the events that are relevant to monitor, as well as geographical and political concepts and issues. Then, the system extracts the relevant

information items from texts, based on linguistic patterns. Finally, the extracted items are fused to deduce synthetic events. The fusion process is based on conceptual graphs. The approach is illustrated using a collection of news and newspaper articles that deal with Ivory Coast.

13.1.31 Threat assessment using context-based tracking in a maritime environment

J George, J Crassidis och T Singh.

The main objective of this work is to model and exploit available maritime contextual information to provide a hypothesis on suspicious vessel maneuvers. This concept involves utilizing the L1 tracking to perform L2/L3 data fusion, i.e. refinement and assessment for situations and threats. A new context-based tracker known as the ConTracker is developed. The purpose of the ConTracker is to incorporate the contextual information into a traditional alpha - beta tracker in such a way so that it provides a repeller or an attractor characteristics to a specific region of interest. Any behavior of the vessel that is inconsistent with the repeller or the attractor characteristics of the current vessel location would be classified as suspicious. Such an inconsistent vessel behavior would be directly indicated by a high measurement residual which may be used to estimate an accurate process noise covariance using a multiple-model adaptive estimator. Based on the rate of change of the estimated process noise covariance values, an L2/L3 hypothesis generator red-flags the target vessel. Simulation results indicate that the context based tracking enhances the reliability of erratic maneuver detection.

13.2   Artiklar från International Conference on Information Fusion 2010 (Fusion 2010)

Ordnat alfabetiskt efter titel.

13.2.1 ALARM for early warning: a lightweight analysis for recognition of menace

K Rein, M Frey, U Schade och S Kawaletz.

Information overflow is a significant and as yet unresolved problem for military, homeland security and law enforcement. Furthermore, quantity is only one part of the intelligence problem: identifying which pieces of information belong together, and assessing the credibility of not only individual pieces of information but also of their correlations to one another complicates things. Automatically sifting, sorting and fusing information garnered from multiple sources into recognizable patterns of behavior and potential threats would provide a distinct operational advantage. This advantage would be clearly increased if the time needed for processing was close to real-time. A number of systems for deeper analysis of potential threats using technologies such as Bayesian networks exist, but tend to be time-intensive. This paper describes a near realtime solution for first-pass processing of inflowing information to provide early warning of developing threats.

13.2.2 A multi-disciplinary university research initiative in hard and soft information fusion: overview, research strategies and initial results

R Nagi, J Llinas, D Hall och J Lavery.

The University at Buffalo (UB) Center for Multisource Information Fusion (CMIF) along with a team including the Pennsylvania State University (PSU), Iona College (Iona), and Tennessee State University (TSU) is conducting research to develop a generalized framework, mathematical techniques, and test and evaluation methods to address the ingestion and harmonized fusion of Hard and Soft information in a distributed Level 1 and Level 2 data fusion environment. The primary Research Thrusts addressed are framed around the major functional components of the JDL Fusion Process; these include:

1. Source Characterization of Soft Data input streams including; human observation—direct, indirect, open source inputs, linguistic framing, and text processing. 2. Common Referencing and Alignment of Hard and Soft Data, especially strategies and methods for meta-data generation for Hard-Soft data normalization. 3. Generalized Data Association Strategies and Algorithms for Hard and Soft Data. 4. Robust Estimation Methods that exploit associated Hard and Soft Data. 5. Dynamic Network-based Effects on Hard-Soft Data Fusion Architectures and Methods. 6. Test and Evaluation Methodology Development to include Human-in-the-Loop. 7. Extensibility, Adaptability, and Robustness Assessment. 8. Fusion Process Framework. 9. Technology Concept of Employment. This program is a large, 5-year effort and considered distinctive in being a major academic thrust into the complexities of the hard and soft fusion problem. This paper summarizes the research strategy, the early technology decisions made, and the very early results of both design approaches and prototyping.

13.2.3 Architecture of knowledge fusion within an integrated mobile security kit

C Laudy, H Petersson och K Sandkhul.

A common challenge for applications requiring information and knowledge fusion is the conversion of data streams into knowledge adapted to the context of usage. In the context of the project Integrated Mobile Security Kit, this paper focuses on the knowledge fusion sub-system. It integrates different fusion aspects based on a common domain model and embedded into a distributed and mobile infrastructure. The fusion aspects considered are attribute and situation fusion, situation recognition and event correlation. The main contribution of the paper are (1) the architecture of the knowledge fusion sub-system, (2) the domain model for integrating the fusion aspects and (3) the specification of the inner workings of the three different fusion aspects.

13.2.4 Assessing confidence in situation awareness

J Palmer.

Situation Awareness enables the discovery of aggregations and the identification of interesting patterns in underlying data that can be leveraged to further the understanding of the battlespace. While there have been steady efforts within the information fusion community to increase the level of automated reasoning supporting Situation Awareness, there remain unresolved issues such as the development of standard metrics of trust. Aggregation methods

applicable to one sort of analysis may not be parameterized in the same fashion as another. New methods may be introduced. Together, these belie the possibility of a universal a-priori understanding of the factors that may temper a method's reliability. To accommodate such variability, this paper adopts a non-parametric approach to the assignment of a confidence metric. It introduces a measure similar to Hubert's Γ but which incorporates a measure previously shown helpful in assessing the effectiveness of object refinement engines. Results illustrate its application.

13.2.5 Current approaches to automated information evaluation and their applicability to priority intelligence requirement answering

B Ulicny, C J Matheus, G M Powell och M M Kokar.

Doctrinally, Priority Intelligence Requirements (PIRs) represent information that the commander needs to know in order to make a decision or achieve a desired effect. Networked warfare provides the intelligence officer with access to multitudes of sensor outputs and reports, often from unfamiliar sources. Counterinsurgency requires evaluating information across all PMESII-PT categories: Political, Military, Economic, Social, Infrastructure Information, Physical Environment and Time. How should analysts evaluate this information? NATO's STANAG (Standard Agreement) 2022 requires that every piece of information in intelligence reports used to answer PIRs should be evaluated along two independent dimensions: the reliability of its source and the credibility of the information. Recent developments in information retrieval technologies, including social search technologies, incorporate metrics of information evaluation, reliability and credibility, such as Google's PageRank. In this paper, we survey various current approaches to automatic information evaluation and explore their applicability to the information evaluation and PIR answering tasks.

13.2.6 Data association and soft data streams

M Hannigan, D McMaster, J Llinas och K Sambhoos.

This paper discusses the challenges of and possible methods for data association in the domain of counterinsurgency where "soft/linguistic" data is an important input data type. An overview of the processing operations from input to construction of fused estimates is described. The design issues that are discussed and require further exploration to yield a workable and efficient association process include developing an input batching logic, finding efficient ways to search between graphs, and the selection of appropriate semantic similarity metrics to associate nodes and arcs. Additionally, the solution to a multi-dimensional assignment problem and graph merging techniques will need to be defined. The application of data association in this type of environment has potential to yield an improved, comprehensive data graph which will aid in reducing search time and provide more accurate results for analysts making real time decisions in the real world.

13.2.7 Description of the Choquet integral for tactical knowledge representation

T Schuck och E Blasch.

The goal of Combat Identification (CID), and as well, Situational Awareness (SA), is to combine data and information at the appropriate information representation in order to declare a positive ID according to a classification structure. CID includes the ultimate determination of the intent and prediction of future actions of an object or entity via the establishment of tactical knowledge. To facilitate CID, we utilize the concept of conceptual spaces to represent cooperative and non-cooperative CID. The Choquet integral combined with Bayes risk enables methods that provide a statistical approach to adversary intent prediction through the CID knowledge spaces. The use of the Choquet Integral for CID is applied in the context of a Maritime Domain Awareness (MDA) example.

13.2.8 Fusion of data from sources with different levels of trust

D Nevell, S Maskell, P Horridge och H Barnett.

In the context of this paper, trust is defined to be "a measure of to what degree an information source is believed to be capable of producing information that conforms to fact." No standard method has been adopted by the intelligence community for fusing data from sources with different levels of trust. This paper proposes an approach that extends the standard application of Bayesian inference to allow for the fact that any piece of intelligence data may be less than fully trustworthy. Based on a prototypical intelligence scenario from which synthetic data was generated, results indicate that trust models produce results which are closer to the ground truth than those for a model containing no trust variables, exhibit less variability and which provide a better basis for making correct decisions.

13.2.9 High-level fusion: issues in developing a formal theory

P Costa, K Chang, K Laskey, T Levitt och W Sun.

Network-centric operations demand an increasingly sophisticated level of interoperation and information fusion for an escalating number and throughput of sensors and human processes. The resulting complexity of the systems being developed to face this environment render lower level fusion techniques alone simply insufficient to ensure interoperability, as they fail to consider subtle, but critical, aspects inherent in knowledge interchange. A fundamental mathematical theory of high-level information fusion is needed to address (1) the representation of semantics and pragmatics, (2) the mathematical framework supporting its algorithmic and computing processes, and (3) scalability of products such as common and user-defined operational pictures. We argue that there is no silver bullet for addressing these elements, and therefore any successful approach to the problem of high-level fusion must be systemic. In this paper, we propose the development of mathematical foundations that systemically address this problem from a decision theoretic perspective, and might seed the development of such fundamental theory. As a case study illustrating these techniques we present our current development of PROGNOS, a HLF system focused on the maritime domain.

13.2.10 Information Quality in Information Fusion

G Rogova och E Bossé.

Designing fusion systems for decision support in complex dynamic situations calls for an integrated human-machine information environment, in which some processes are best executed automatically while for others the judgment and guidance of human experts and end-

users are critical. Thus decision making in such environment requires constant information exchange between human and automated agents that utilize operational data, data obtained from sensors, intelligence reports, and open source information. The quality of decision making strongly depends on the success of being aware of, and compensating for, insufficient information quality at each step of information exchange. Designing the methods of representing and incorporating information quality into this environment is a relatively new and a rather difficult problem. The paper discusses major challenges and suggests some approaches to address this problem.

13.2.11 Issues and Challenges in Higher Level Fusion: Threat/Impact Assessment and Intent Modeling (A Panel Summary)

J J Salerno, G P Tadda, M Sudit, S J Yang, I Kadar och J Holsopple.

Many say that we live in the information age, but in reality if you ask any analyst today they would say we live in the data age. The amount of data being presented and displayed to the analyst is overwhelming - to a point that in many cases they are missing the salient or key activities of interest. Analysts are spending the majority of their time filtering through the data rather than performing analysis. Over the past 10 years, there has been an increasing emphasis on research in higher level fusion or what many are calling situation awareness. In this paper, we describe a collection of research addressing the challenges of enabling situation awareness. We will review our reference model and provide a discussion of a flow through the model to include how we can rank various activities based on their impact and threat. We also provide a number of algorithms that have been implemented and then tested and evaluated using a set of performance metrics.

13.2.12 Kalman filtering for compressed sensing

D Kanevsky, L Horesh, B Ramabhadran, T Sainath, P Gurfil och A Carmi.

Compressed sensing is a new emerging field dealing with the reconstruction of a sparse or, more precisely, a compressed representation of a signal from a relatively small number of observations, typically less than the signal dimension. In our previous work we have shown how the Kalman filter can be naturally applied for obtaining an approximate Bayesian solution for the compressed sensing problem. The resulting algorithm, which was termed CSKF, relies on a pseudo-measurement technique for enforcing the sparseness constraint. Our approach raises two concerns which are addressed in this paper. The first one refers to the validity of our approximation technique. In this regard, we provide a rigorous treatment of the CSKF algorithm which is concluded with an upper bound on the discrepancy between the exact (in the Bayesian sense) and the approximate solutions. The second concern refers to the computational overhead associated with the CSKF in large scale settings. This problem is alleviated here using an efficient measurement update scheme based on Krylov subspace method.

13.2.13 Maritime anomaly detection and threat assessment

R O Lane, D A Nevell, S D Hayward och T W Beaney.

Ships involved in commercial activities tend to follow set patterns of behaviour depending on the business in which they are engaged. If a ship exhibits anomalous behaviour, this could indicate it is being used for illicit activities. With the wide availability of automatic identification system (AIS) data it is now possible to detect some of these patterns of behaviour. Monitoring the possible threat posed by the worldwide movement of ships, however, requires efficient and robust automatic data processing to create a priority list for further investigation. This paper outlines five anomalous ship behaviours: deviation from standard routes, unexpected AIS activity, unexpected port arrival, close approach, and zone entry. For each behaviour, a process is described for determining the probability that it is anomalous. Individual probabilities are combined using a Bayesian network to calculate the overall probability that a specific threat is present. Examples of how the algorithms work are given using simulated and real data.

13.2.14 Measures of effectiveness for high-level fusion

E Blasch, P Valin och E Bossé.

Current advances in technology, sensor collection, data storage, and data distribution have afforded more complex, distributed, and operational information fusion systems (IFSs). IFSs notionally consist of low-level (data collection, registration, and association in time and space) and high-level fusion (user coordination, situational awareness, and mission control). Low-level IFSs typically rely on standard metrics for evaluation such as timeliness, accuracy, and confidence. Given the broader use of IFSs, it is also important to look at high-level fusion processes and determine a set of metrics to test IFSs, such as workload, throughput, and cost. Three types of measures (measures of performance MOP, measures of effectiveness MOE, and measures of merit MOM) are summarized. In this paper, we seek to describe MOEs for High-Level Fusion (HLF) based on developments in Quality of Service (QOS) and Quality of Information (QOI) that support the user and the machine, respectively. We define a HLF MOE based on (1) information quality, (2) robustness, and (3) information gain. We demonstrate the HLF MOE based for a maritime domain situation awareness example.

13.2.15 Multiple Hypothesis Situation Analysis Support System Prototype

J Roy och A Bergeron.

Uncertainty makes the analysis of even simple situations difficult. It forces intelligence analysts to formulate and manage hypotheses during the construction of explicit representations of real world situations. This may quickly become overwhelming. To provide better support to the intelligence staff, the main concepts behind multiple hypothesis tracking have been revisited to develop a proof-of-concept prototype of a multiple hypothesis situation analysis (MHSA) support system. A key objective is to showcase the potential and utility of MHSA. It has thus been conceived to allow users, developers, and managers to better understand each and every aspect of the MHSA process, which isn't like a Bayesian Net. This paper discusses a situation modeling graphical language, the interdependency and uncertainty about the situation model components, the hypothesis tree data structure used to keep track of the uncertainty, different issues regarding the hypothesis tree, hypothesis scoring, and user interactions with the MHSA support system prototype.

13.2.16 On the efficiency of semantic web based context computing infrastructures

A Garcia-Sola, T Garcia-Valverde, F Lopez-Marmol och J A Botia.

We present in this paper the results of testing the OCP2 middleware. OCP2 is an efficient middleware for context information management with reasoning capabilities based on semantic web, which offers different ways to express real world behavior (such as rules or patterns), modeling them on top of the ontology. More specifically, we focus on its performance and scalability. Performance has always been one of the biggest drawbacks of the semantic web, and we have work hard to change this. The results are outstanding marks using hundreds of simultaneous users.

13.2.17 Ontology alignment in geographical hard-soft information fusion systems

E Blasch, E Dorion, P Valin, E Bossé och J Roy.

Information fusion exists over many forms of hard data (e.g. from physical sensors) and soft data (e.g. from human reports) to interpret observations of real-world objects. As demonstrated from the Geographical Information Systems (GIS) community, there is a growing need for the linking and alignment of both (1) exploited physical imagery products and (2) derived ontological textual labels (semantic markup). Semantic markup can be done on both exploited data (e.g. automated image segmentation), as well as user reports (e.g. weather forecasts). Since the derived information is collected, stored, and displayed into distinct ontological structures by different agencies; ontological alignment is thus required whenever the semantic information is paired with distinct real-world imagery observations. In this paper, we explore issues of fusing hard and soft data as related to ontology alignment. A maritime domain situational awareness example with geographical imagery and textural ontologies is shown to demonstrate the need for ontology alignment to assist users for pragmatic surveillance.

13.2.18 Plan detection under partially observable and cluttered conditions

G Mathews, D Nicholson, A McCabe och M Williams.

This paper examines the problem of detecting the execution of plans performed in partially observable and cluttered environments. In particular, a plan is defined as a series of tasks that must be executed according to a known precedence relation and build toward some final objective. The goal of a plan detection algorithm is to detect the execution of the plan from the available ambiguous and incomplete data before it reaches the terminal event. This paper presents a Monte Carlo inference algorithm capable of estimating the belief that the plan is currently being executed and how much progress has been made. The performance characteristics of the algorithm are tested for a variety of simulated data sets containing different signal to noise ratios.

13.2.19 Probabilistic behaviour signatures: feature-based behaviour recognition in data-scarce domains

R Baxter, N M Robertson och D Lane.

In this paper we present a new method to provide situation awareness via the automatic recognition of behaviour in video. In contrast to many other approaches, the presented method does not require many training exemplars. We introduce Probabilistic Behaviour Signatures to represent the goals of a person agent as sets of features. We do not assume temporal ordering of observed actions is necessary. Inference is performed using an extension of the Rao-Blackwellised Particle Filter. We validate our approach using simulated image trajectories which represent three high-level behaviours. We compare performance to a trained Hidden Markov Model Particle Filter (HMM PF) and show that our approach achieves 92% accuracy at video frame rate. Our method is also significantly more robust than the HMM PF in the presence of noise.

13.2.20 PROGNOS: predictive situational awareness with probabilistic ontologies

R Carvalho, P Costa, K Laskey och K C Chang.

Information in the battlefield comes from reports from diverse sources, in distinct syntax, and with different meanings. There are many kinds of uncertainty involved in this process, e.g., noise in sensors, incorrect, incomplete, or deceptive human intelligence, and others, which makes it essential to have a coherent, consistent, and principled means to represent such phenomena among the systems performing Predictive Situation Awareness (PSAW). PROGNOS is a PSAW system being developed to work within the operational context such as U.S. Navy's FORCENet. It employs probabilistic ontologies in a distributed system architecture as a means to provide semantic interoperability within an intrinsically complex and uncertain environment. This paper explores our current status in developing the system while addressing the major research challenges for making an effective PSAW system to support maritime operations.

13.2.21 Revisiting the role of abductive inference in fusion domain

G Ferrin, L Snidaro och G Foresti.

Abductive inference plays a very important role in the fusion domain, seen as a "conceptual framework" driving the conjecturing and hypothesizing process mainly aimed to discover relationships. Unfortunately, despite the recent gained attention in several fields as philosophy of science and logic, and the ongoing debate, in the fusion domain almost only one kind of abductive inference is taken under consideration with the aim of developing successful tools to be deployed within a fusion process, namely "Inference to the Best Explanation". The issues faced in the domain of intelligence and information fusion, dealing with the real world, imply processes which follow the sequences of scientific discovery and proof. Therefore a survey of some key concepts around abductive inference in the domain of epistemology can reveal some principles to be directly applied to the Fusion domain.

13.2.22 Soft information, dirty graphs and uncertainty representation/processing for situation understanding

G Gross, R Nagi och K Sambhoos.

In conventional warfare as well as counter-insurgency (COIN) operations, the understanding of the situation is extremely vital to assure a sense of security. Intelligence in COIN is about people, and deployed units in the field are the best sources of intelligence. Past and present intelligence data is analyzed to look for changes in the insurgents' approach or tactics. To do this, graphical methods have proven to be effective. In recent work, [10], have developed an inexact subgraph matching algorithm as a variation of the subgraph isomorphism approach for situation assessment. This paper enhances this procedure to represent inaccurate observations or data estimates, and inaccurate structural representations of a state of interest, thus accounting for the uncertainties. Various probabilistic and possibilistic uncertainty representations, transformations between representations and methods for establishing similarities between representations have been reviewed. This comprehensible approach will give pragmatic estimates providing rigor and sound understanding during situation assessment.

13.2.23 Strategies and techniques for use and exploitation of contextual information in high-level fusion architectures

J Gómez-Romero, J García, J M Molina, M A Patricio, J Llinas, M Kandefer, M Prentice och S C Shapiro.

Contextual Information is proving to be not only an additional exploitable information source for improving entity and situational estimates in certain Information Fusion systems, but can also be the entire focus of estimation for such systems as those directed to Ambient Intelligence (AI) and Context-Aware(CA) applications. This paper will discuss the role(s) of Contextual Information (CI) in a wide variety of IF applications to include AI, CA, Defense, and Cybersecurity among possible others, the issues involved in designing strategies and techniques for CI use and exploitation, provide some exemplars of evolving CI use/exploitation designs on our current projects, and describe some general frameworks that are evolving in various application domains where CI is proving critical.

13.2.24 Test and evaluation of soft / hard information fusion systems: a test environment, methodology and initial data sets

D Hall, J Graham, L More och J Rimland.

Increasing interest in human-centered information fusion systems involves; (1) humans as sensors (viz., "soft sensors"), (2) humans performing pattern recognition and participating in the fusion cognitive process, and (3) human groups performing collaborative analysis (viz., "crowd-sourcing" of analysis). Test and evaluation of such systems is challenging because we must develop both representative test data (involving both physical sensors and human observers) and test environments to evaluate the performance of the hardware, software and humans-in-the-loop. This paper describes an experimental facility called an extreme events laboratory, a test and evaluation approach, and evolving test data sets for evaluation of human-centered information fusion systems for situation awareness. The data sets include both synthetic data as well as data obtained using human subjects in campus wide experiments.

13.2.25 Testbed for distributed high-level information fusion and dynamic resource management

P Valin, E Bossé, A Guitouni, H When och J Happe.

The testbed allows experimenting with high-level distributed information fusion, dynamic resource management and configuration management given multiple constraints on the resources and their communication networks. The testbed provides general services that are useful for testing many information fusion applications. Services include a multi-layer plug-and-play architecture, and a general multi-agent framework based on John Boyd's OODA loop.

13.2.26 Tractor: a framework for soft information fusion

M Prentice, M Kandefer och S C Shapiro.

This paper presents a soft information fusion framework for creating a propositional graph from natural language messages with an emphasis on producing these graphs for fusion with other messages. The framework utilizes artificial intelligence techniques from natural language understanding, knowledge representation, and information retrieval.

13.3 Artiklar från SPIE Defence and Security 2009

Ordnat efter volyms- och artikelnummer.

13.3.1 Sensor management using a new framework for observation modeling

Mark P. Kolba och Leslie M. Collins. Proc. SPIE, Vol. 7303, 730326 (2009).

In previous work, a sensor management framework has been developed that manages a suite of sensors in a search for static targets within a grid of cells. This framework has been studied for binary, non-binary, and correlated sensor observations, and the sensor manager was found to outperform a direct search technique with each of these different types of observations. Uncertainty modeling for both binary and non-binary observations has also been studied. In this paper, a new observation model is introduced that is motivated by the physics of static target detection problems such as landmine detection and unexploded ordnance (UXO) discrimination. The new observation model naturally accommodates correlated sensor observations and models both the correlation that occurs between observations made by different sensors and the correlation that occurs between observations made by the same sensor. Uncertainty modeling is also implicitly incorporated into the observation model because the underlying parameters of the target and clutter cells are allowed to vary and are not assumed to be constant across target cells and across clutter cells. Sensor management is then performed by maximizing the expected information gain that is made with each new sensor observation. The performance of the sensor manager is examined through performance evaluation with real data from the UXO discrimination application. It is demonstrated that the sensor manager is able to provide comparable detection performance to a direct search strategy using fewer sensor observations than direct search. It is also demonstrated that the sensor manager is able to ignore features that are uninformative to the discrimination problem.

13.3.2 Automatic cuing of human-in-the-loop detection system

J M Keller, K E Stone, D K C Ho och M Popescu. Proc. SPIE, Vol. 7303, 73032C (2009).

Rapid detection of landmines and explosive hazards is a critical issue for modern military operations. Due to the varied nature of the objects of interest and the complexity of the surrounding, one approach is to utilize the superior recognition capabilities of the human brain in the detection process. We are developing frameworks and algorithms to fuse image data from multiple sources and to provide cuing capability for a human-in-the-loop detection system.

13.3.3 STIDP: A U.S. Department of Homeland Security program for countering explosives attacks at large public events and mass transit facilities

C K Knudson, M C Kemp och N J Lombardo. Proc. SPIE, Vol. 7305, 73050Y (2009).

The U.S. Department of Homeland Security's Standoff Technology Integration and Demonstration Program is designed to accelerate the development and integration of technologies, concepts of operations, and training to defeat explosives attacks at large public events and mass transit facilities. The program will address threats posed by suicide bombers, vehicle-borne improvised explosive devices, and leave-behind bombs. The program is focused on developing and testing explosives countermeasure architectures using commercial off-the-shelf and near-commercial standoff and remotely operated detection technologies in prototypic operational environments. An important part of the program is the integration of multiple technologies and systems to protect against a wider range of threats, improve countermeasure performance, increase the distance from the venue at which screening is conducted, and reduce staffing requirements. The program will routinely conduct tests in public venues involving successively more advanced technology, higher levels of system integration, and more complex scenarios. This paper describes the initial field test of an integrated countermeasure system that included infrared, millimeter-wave, and video analytics technologies for detecting person-borne improvised explosive devices at a public arena. The test results are being used to develop a concept for the next generation of integrated countermeasures, to refine technical and operational requirements for architectures and technologies, and engage industry and academia in solution development.

13.3.4 An extreme events laboratory to provide network centric collaborative situation assessment and decision making

B J Panulla, L D More, W R Shumaker, M D Jones, R Hooper, J M Vernon och S G Aungst. Proc. SPIE, Vol. 7305, 73050W (2009).

Rapid improvements in communications infrastructure and sophistication of commercial hand-held devices provide a major new source of information for assessing extreme situations such as environmental crises. In particular, ad hoc collections of humans can act as "soft sensors" to augment data collected by traditional sensors in a net-centric environment (in effect, "crowd-sourcing" observational data). A need exists to understand how to task such soft sensors, characterize their performance and fuse the data with traditional data sources. In order to quantitatively study such situations, as well as study distributed decision-making, we have developed an Extreme Events Laboratory (EEL) at The Pennsylvania State University. This facility provides a network-centric, collaborative situation assessment and decision-making

capability by supporting experiments involving human observers, distributed decision making and cognition, and crisis management. The EEL spans the information chain from energy detection via sensors, human observations, signal and image processing, pattern recognition, statistical estimation, multi-sensor data fusion, visualization and analytics, and modeling and simulation. The EEL command center combines COTS and custom collaboration tools in innovative ways, providing capabilities such as geo-spatial visualization and dynamic mash-ups of multiple data sources. This paper describes the EEL and several on-going human-in-the-loop experiments aimed at understanding the new collective observation and analysis landscape.

13.3.5 CPHD and PHD filters for unknown backgrounds I: dynamic data clustering

R Mahler. Proc. SPIE, Vol. 7330, 73300K (2009).

The probability hypothesis density (PHD) and cardinalized PHD (CPHD) filters were introduced in 2000 and 2006, respectively, as approximations of the full multitarget Bayes detection and tracking filter. Both filters are based on the "standard" multitarget measurement model that underlies most multitarget tracking theory. This paper is part of a series of theoretical studies that addresses PHD and CPHD filters for nonstandard multitarget measurement models. In this paper I derive the measurement-update equations for CPHD and PHD filters that estimate models of unknown, dynamically changing data, such as background clutter. A companion paper generalizes these results to multitarget detection and tracking in unknown, dynamic clutter.

13.3.6 CPHD and PHD filters for unknown backgrounds II: multitarget filtering in dynamic clutter

R Mahler. Proc. SPIE, Vol. 7330, 73300L (2009).

The probability hypothesis density (PHD) and cardinalized PHD (CPHD) filters were introduced in 2000 and 2006, respectively, as approximations of the full multitarget Bayes detection and tracking filter. Both filters are based on the "standard" multitarget measurement model that underlies most multitarget tracking theory. This paper is part of a series of theoretical studies that addresses PHD and CPHD filters for nonstandard multitarget measurement models. In a companion paper I derived the measurement-update equations for CPHD and PHD filters for extracting clusters from dynamically evolving data sets. This paper uses these results to derive CPHD and PHD filters for detecting and tracking multiple targets obscured by unknown, dynamically changing clutter.

13.3.7 Game-theoretic homological sensor resource management for SSA

S P Chin. Proc. SPIE, Vol. 7330, 73300O (2009).

We present a game-theoretic approach to Level 2/3/4 fusion for the purpose of Space Situational Awareness (SSA) along with prototypical SW implementation of this approach to demonstrate its effectiveness for possible future space operations. Our approach is based upon innovative techniques that we are developing to solve dynamic games and Nperson cooperative/non-cooperative games, as well as a new emerging homological sensing

algorithms which we apply to control disparate network of space sensors in order to gain better SSA.

13.3.8 Contextual object understanding through geospatial analysis and reasoning (COUGAR)

J Douglas, M Antone, J Coggins, B J Rhodes, E Sobel, F Stolle, L Vinciguerra, M Zandipour och Y Zhong. Proc. SPIE, Vol. 7335, 733506 (2009).

Military operations in urban areas often require detailed knowledge of the location and identity of commonly occurring objects and spatial features. The ability to rapidly acquire and reason over urban scenes is critically important to such tasks as mission and route planning, visibility prediction, communications simulation, target recognition, and inference of higher-level form and function. Under DARPA's Urban Reasoning and Geospatial ExploitatioN Technology (URGENT) Program, the BAE Systems team has developed a system that combines a suite of complementary feature extraction and matching algorithms with higher-level inference and contextual reasoning to detect, segment, and classify urban entities of interest in a fully automated fashion. Our system operates solely on colored 3D point clouds, and considers object categories with a wide range of specificity (fire hydrants, windows, parking lots), scale (street lights, roads, buildings, forests), and shape (compact shapes, extended regions, terrain). As no single method can recognize the diverse set of categories under consideration, we have integrated multiple state-of-the-art technologies that couple hierarchical associative reasoning with robust computer vision and machine learning techniques. Our solution leverages contextual cues and evidence propagation from features to objects to scenes in order to exploit the combined descriptive power of 3D shape, appearance, and learned inter-object spatial relationships. The result is a set of tools designed to significantly enhance the productivity of analysts in exploiting emerging 3D data sources.

13.3.9 Comparison of kernel based PDF estimation methods

D E Freund, P Burlina, A Banerjee och E Justen. Proc. SPIE, Vol. 7335, 733508 (2009).

There are a number of challenging estimation, tracking, and decision theoretic problems that require the estimation of Probability Density Functions (PDFs). When using a traditional parametric approach, the functional model of the PDF is assumed to be known. However, these models often do not capture the complexity of the underlying distribution. Furthermore, the problems of validating the model and estimating its parameters are often complicated by the sparsity of prior examples. The need for exemplars grows exponentially with the dimension of the feature space. These methods may yield PDFs that do not generalize well to unseen data because these tend to overfit or underfit the training exemplars. We investigate and compare alternate approaches for estimating a PDF and consider instead kernel based estimation methods which generalize the Parzen estimator and use a Linear Mixture of Kernels (LMK) model. The methods reported here are derived from machine learning methods such as the Support Vector Machines and the Relevance Vector Machines. These PDF estimators provide the following benefits: (a) they are data driven; (b) they do not overfit the data and consequently have good generalization properties; (c) they can accommodate highly irregular and multi-modal data distributions; (d) they provide a sparse and succinct description of the underlying data which leads to efficient computation and communication. Comparative experimental results are provided illustrating these properties using simulated Mixture of Gaussian-distributed data.

13.3.10 Gradient estimation for particle flow induced by log-homotopy for nonlinear filters

F Daum, J Huang, A J Noushin och M Krichman. Proc. SPIE, Vol. 7336, 733602 (2009).

We study 17 distinct methods to approximate the gradient of the log-homotopy for nonlinear filters. This is a challenging problem because the data are given as function values at random points in high dimensional space. This general problem is important in optimization, financial engineering, quantum chemistry, chemistry, physics and engineering. The best general method that we have developed so far uses a simple idea borrowed from geology combined with a fast approximate k-NN algorithm. Extensive numerical experiments for five classes of problems shows that we get excellent performance.

13.3.11 Nonlinear filters with particle flow induced by log-homotopy

F Daum och J Huang. Proc. SPIE, Vol. 7336, 733603 (2009).

We solve the fundamental and well known problem in particle filters, namely "particle collapse" or "particle degeneracy" as a result of Bayes' rule. We do not resample, and we do not use any proposal density; this is a radical departure from other particle filters. The new filter implements Bayes' rule using particle flow rather than with a pointwise multiplication of two functions. We show numerical results for a new filter that is vastly superior to the classic particle filter and the extended Kalman filter. In particular, the computational complexity of the new filter is many orders of magnitude less than the classic particle filter with optimal estimation accuracy for problems with dimension greater than 4. Moreover, our new filter is two orders of magnitude more accurate than the extended Kalman filter for quadratic and cubic measurement nonlinearities. We also show excellent accuracy for problems with multimodal densities.

13.3.12 The multisensor PHD filter: II. Erroneous solution via Poisson magic

R Mahler. Proc. SPIE, Vol. 7336, 73360D (2009).

The theoretical foundation for the probability hypothesis density (PHD) filter is the FISST multitarget differential and integral calculus. The "core" PHD filter presumes a single sensor. Theoretically rigorous formulas for the multisensor PHD filter can be derived using the FISST calculus, but are computationally intractable. A less theoretically desirable solution-the iterated-corrector approximation-must be used instead. Recently, it has been argued that an "elementary" methodology, the "Poisson-intensity approach," renders FISST obsolete. It has further been claimed that the iterated-corrector approximation is suspect, and in its place an allegedly superior "general multisensor intensity filter" has been proposed. In this and a companion paper I demonstrate that it is these claims which are erroneous. The companion paper introduces formulas for the actual "general multisensor intensity filter." In this paper I demonstrate that (1) the "general multisensor intensity filter" fails in important special cases; (2) it will perform badly in even the easiest multitarget tracking problems; and (3) these rather serious missteps suggest that the "Poisson-intensity approach" is inherently faulty.

13.3.13 The multisensor PHD filter: I. General solution via multitarget calculus

R. Mahler. Proc. SPIE, Vol. 7336, 73360E (2009).

The theoretical foundation for the probability hypothesis density (PHD) filter is the FISST multitarget differential and integral calculus. The "core" PHD filter presumes a single sensor. Theoretically rigorous formulas for the multisensor PHD filter can be derived using the FISST calculus, but are computationally intractable. A less theoretically desirable solution-the iterated-corrector approximation-must be used instead. Recently, it has been argued that an "elementary" methodology, the "Poisson-intensity approach," renders FISST obsolete. It has further been claimed that the iterated-corrector approximation is suspect, and in its place an allegedly superior "general multisensor intensity filter" has been proposed. In this and a companion paper I demonstrate that it is these claims which are erroneous. This paper introduces formulas for the actual "general multisensor intensity filter." In the companion paper I demonstrate that the "general multisensor intensity filter" will perform badly in even the easiest multitarget tracking problems; and argue that this suggests that the "Poisson-intensity approach" is inherently faulty.

13.3.14 Maneuvering target tracking using probability hypothesis density smoothing

N Nadarajah och T Kirubarajan. Proc. SPIE, Vol. 7336, 73360F (2009).

The Probability Hypothesis Density (PHD) filter is a computationally tractable alternative to the optimal nonlinear filter. The PHD filter propagates the first moment instead of the full posterior density. Evaluation of the PHD enables one to extract the number of targets as well as their individual states from noisy data with data association uncertainties. Recently, a smoothing algorithm was proposed by the authors to improve the capability of PHD based tracking. Smoothing produces delayed estimates, which yield better estimates not only for the target states but also for the unknown number of targets. However, in the case of the maneuvering target tracking problem, this single model method may not provide accurate estimates. In this paper, a multiple model PHD smoothing method is proposed to improve the tracking of multiple maneuvering targets. A fast sequential Monte Carlo implementation for a special case is also provided. Simulations are performed with the proposed method consisting of multiple maneuvering targets. Simulation results confirm the improved performance of the proposed algorithm.

13.3.15 Joint target-detection and tracking smoothers

D Clark. Proc. SPIE, Vol. 7336, 73360G (2009).

A multi-object Bayes filter analogous to the single-object Bayes filter can be derived using Finite Set Statistics for the estimation of an unknown and randomly varying number of target states from random sets of observations. The joint target-detection and tracking (JoTT) filter is a truncated version of the multi-object Bayes filter for the single target detection and tracking problem. Despite the success of Finite-Set Statistics for multi-object Bayesian filtering, the problem of multi-object smoothing with Finite Set Statistics has yet to be addressed. I propose multi-object Bayes versions of the forward-backward and two-filter smoothers and derive optimal non-linear forward-backward and two-filter smoothers for jointly detecting, estimating and tracking a single target in cluttered environments. I also derive optimal Probability

Hypothesis Density (PHD) smoothers, restricted to a maximum of one target and show that these are equivalent to their Bayes filter counterparts.

13.3.16 Dispersed and disparate sensor management for tracking low earth orbit satellites

A Zatezalo, A. El-Fallah, R Mahler, R K Mehra och J Brown. Proc. SPIE, Vol. 7336, 73360I (2009).

Optimal sensor management of dispersed and disparate sensors for tracking Low Earth Orbit (LEO) objects presents a daunting theoretical and practical challenge since it requires the optimal utilization of different types of sensors and platforms that include Ground Based Radars (GBRs) positioned throughout the globe, and the Space Based Visible (SBV) sensor on board LEO platforms. We derive and demonstrate new computationally efficient algorithms for multisensor-multiobject tracking of LEO objects. The algorithms are based on the Posterior Expected Number of Objects as the sensor management objective function, observation models for the sensors/platforms, and the Probability Hypothesis Density Particle Filter (PHD-PF) tracker.

13.3.17 First-principles mapping of fusion applications into the JDL model

R T Antony och J A Karakowski. Proc. SPIE, Vol. 7336, 73360J (2009).

The paper presents a formal approach for mapping from an entity-relationship model of a selected application domain to the functional components of the JDL fusion model. The resultant functional decomposition supports both traditional sensor, as well as human-generated text input. To demonstrate the generality of the mapping, examples are offered for three distinct application domains: (1) Intelligence Fusion, (2) Aircraft Collision Avoidance, and (3) Robotic Control. The first-principle's based approach begins by viewing fusion as the composition of similar and dissimilar entities. Next, the fusion triple (entity, location, time) is defined where entities can be either physical or non-physical. Coupling the fusion triple with this generalized view of fusion leads to the identification of eight base-level fusion services that serve as the building blocks of individual composition products.

13.3.18 A risk-based comparison of classification systems

S Thorsen, S Wagenman, M E Oxley och K W. Bauer. Proc. SPIE, Vol. 7336, 73360T (2009).

Performancemeasures for families of classification system families that rely upon the analysis of receiver operating characteristics (ROCs), such as area under the ROC curve (AUC), often fail to fully address the issue of risk, especially for classification systems involving more than two classes. For the general case, we denote matrices of class prevalence, costs, and class-conditional probabilities, and assume costs are subjectively fixed, acceptable estimates for expected values of class-conditional probabilities exist, and mutual independence between a variable in one such matrix and those of any other matrix. The ROC Risk Functional (RRF), valid for any finite number of classes, has an associated parameter argument, which specifies a member of a family of classification systems, and for which there is an associated classification system minimizing Bayes risk over the family. We typify joint distributions for class prevalences over standard simplices by means of uniform and beta distributions, and

create a family of classification systems using actual data, testing independence assumptions under two such class prevalence distributions. Examples are given where the risk is minimized under two different sets of costs.

13.3.19 Multi-sensor management for data fusion in target tracking

X Li, G Chen, E Blasch, J Patrick, C Yang och I Kadar. Proc. SPIE, Vol. 7336, 73360Y (2009).

Multi-sensor management for data fusion in target tracking concerns issues of sensor assignment and scheduling by managing or coordinating the use of multiple sensor resources. Since a centralized sensor management technique has a crucial limitation in that the failure of the central node would cause whole system failure, a decentralized sensor management (DSM) scheme is increasingly important in modern multi-sensor systems. DSM is afforded in modern systems through increased bandwidth, wireless communication, and enhanced power. However, protocols for system control are needed to management device access. As game theory offers learning models for distributed allocations of surveillance resources and provides mechanisms to handle the uncertainty of surveillance area, we propose an agent-based negotiable game theoretic approach for decentralized sensor management (ANGADS). With the decentralized sensor management scheme, sensor assignment occurs locally, and there is no central node and thus reduces the risk of whole-system failure. Simulation results for a multi-sensor target-tracking scenario demonstrate the applicability of the proposed approach.

13.3.20 Exploring social relations for the intrusion detection in ad hoc networks

W Wang och H Man. Proc. SPIE, Vol. 7344, 734402 (2009).

We proposed a novel intrusion detection system in mobile ad hoc networks using the social network analysis approach, which is different from the conventional ones. Our social based IDS utilizes explored social relations for anomaly detections, which can capture and represent similar network statistics as those used in data mining based intrusion detection systems. Simulation results show that this social based IDS can effectively detect attacks with high detection rates and low false alarm rates. Further more, our system is of simpler implementation and lower system complexity than rule based anomaly IDS.

13.3.21 Estimating the threshold for maximizing expected gain in supervised discrete Bayesian classification

R S Lynch, Jr. och P K Willett. Proc. SPIE, Vol. 7344, 734408 (2009).

When mining discrete data to train supervised discrete Bayesian classifiers, it is often of interest to determine the best threshold setting for maximizing performance. In this work, we utilize a discrete Bayesian classification model, and a gain function, to determine the best threshold setting for a given number of training data under each class. Results are demonstrated for simulated data by plotting the expected gain versus threshold settings for different numbers of discrete training data. In general, it is shown that the expected gain reaches a maximum at a certain threshold. Further, this maximum point varies with the overall

quantization of the data. Additional results are also shown for different gain functions on the decision variable.

13.3.22 Autonomous journaling response using data model LUTS

H Jaenisch, J Handley, N Albritton, D Whitener, R Burnett, R Caspers, S Moren, T Alexander, W Maddox III och W Albritton, Jr. Proc. SPIE, Vol. 7344, 734409 (2009).

Matching journal entries to appropriate context responses can be a daunting problem, especially when there are no salient keyword matches between the entry and the proposed library of appropriate responses. We examine a real-world application for matching interactive journaling requests for guidance to an a priori established archive of sufficient multimedia responses. We show the analysis required to enable a Data Model based algorithm to group journaling entries according to intrinsic context information and type. We demonstrate a new lookup table (LUT) classifier that exploits all available data in LUT form.

13.3.23 A multi-layer network architecture for dynamic resource configuration and management of multiple mobile resources in maritime surveillance

R Farahbod, U Glässer och A Khalili. Proc. SPIE, Vol. 7345, 734508 (2009).

Maritime surveillance of large volume traffic demands robust and scalable network architectures for distributed information fusion. Operating in an adverse and unpredictable environment, the ability to flexibly adapt to dynamic changes in the availability of mobile resources and the services they provide is critical for the success of the surveillance and rescue missions. We present here an extended and enhanced version of the Dynamic Resource Configuration $ Management Architecture (DRCMA), with new features and improved algorithms to better address the adaptability requirements of such a resource network. The DRCMA system concept is described in abstract functional and operational terms based on the Abstract State Machine (ASM) paradigm and the CoreSM open source tool environment for modeling dynamic properties of distributed systems.

13.3.24 Semantic enrichment of multi-intelligence data within a net-centric environment

R D Hull, L Lashine och D Jenkins. Proc. SPIE, Vol. 7345, 734509 (2009).

The challenges of predictive battlespace awareness and transformation of TCPED to TPPU processes in a netcentric environment are numerous and complex. One of these challenges is how to post the information with the right metadata so that it can be effectively discovered and used in an ad hoc manner. We have been working on the development of a semantic enrichment capability that provides concept and relationship extraction and automatic metadata tagging of multi-INT sensor data. Specifically, this process maps multi-source data to concepts and relationships specified within a semantic model (ontology). We are using semantic enrichment for development of data fusion services to support Army and Air Force programs. This paper presents an example of using the semantic enrichment architecture for concept and relationship extraction from USMTF data. The process of semantic enrichment adds semantic metadata tags to the original data enabling advanced correlation and fusion. A

geospatial user interface leverages the semantically-enriched data to provide powerful search, correlation, and fusion capabilities.

13.3.25 An integrated multi-source JDL high-level fusion architecture using recombinant cognition synthesis

M A Solano, S Ekwaro-Osire och M M Tanik. Proc. SPIE, Vol. 7345, 73450B (2009).

High-Level fusion systems based on the JDL model are relatively immature. Current solutions lack a comprehensive ability to manage multi-source data in a multi-dimensional vector space, and generally do not integrate collection to action models in a cohesive thread. Recombinant Cognition Synthesis (RCS) leverages best-of-breed techniques with a geospatial, temporal and semantic data model to provide a unified methodology that recombines multi-source data with analytic and predictive algorithms to synthesize actionable intelligence. This architecture framework enables the traversal of entity relationships at different level of granularities and the discovery of latent knowledge, thereby facilitating the domain problem analysis and the development of a Course-of-Action to mitigate adversarial threats. RCS also includes process refinement techniques to achieve superior information dominance, by incorporating specialized metadata. This comprehensive and unified methodology delivers enhanced utility to the intelligence analyst, and addresses key issues of relevancy, timeliness, accuracy, and uncertainty by providing metrics via feedback loops within the RCS infrastructure that augment the efficiency and effectiveness of the end-to-end fusion processing chain.

13.3.26 Data Fusion Engine (DFE) for the Force Protection Joint Experiment (FPJE)

C M Barngrover, R T Laird, T A Kramer, J R Cruickshanks och S H Cutler. Proc. SPIE, Vol. 7345, 73450D (2009).

The FPJE was an experiment to consider the best way to create a system of systems in the realm of Force Protection. It was sponsored by Physical Security Equipment Action Group (PSEAG) and Joint Program Manager - Guardian (JPMG), and was managed by the Product Manager - Force Protection Systems (PM-FPS). The experiment attempted to understand the challenges associated with integrating disparate systems into a cohesive unit, and then the compounding challenge of handling the flow of data into the system and its dispersion to all subscribed Command and Control (C2) nodes. To handle this data flow we created the DFE based on the framework of the Joint Battlespace Command and Control System for Manned and Unmanned Assets (JBC2S). The DFE is a data server that receives information from the network of systems via the Security Equipment Integration Working Group (SEIWG) ICD-0100 protocol, processes the data through static fusion algorithms, and then publishes the fused data to the C2 nodes, in this case JBC2S and the Tactical Automated Security System (TASS). The DFE uses only known concepts and algorithms for its fusion efforts. This paper discusses the analyzed impact of the fusion on C2 nodes displays and in turn on the operators. Also, this paper discusses the lessons learned about networked control combined with DFE generated automatic response. Finally, this paper discusses possible future efforts and their benefits for providing the useful operational picture to the operator.

13.3.27 FuzzyFusion: an application architecture for multisource information fusion

K L Fox och R R Henning. Proc. SPIE, Vol. 7345, 73450E (2009).

The correlation of information from disparate sources has long been an issue in data fusion research. Traditional data fusion addresses the correlation of information from sources as diverse as single-purpose sensors to all-source multi-media information. Information system vulnerability information is similar in its diversity of sources and content, and in the desire to draw a meaningful conclusion, namely, the security posture of the system under inspection. FuzzyFusionTM, A data fusion model that is being applied to the computer network operations domain is presented. This model has been successfully prototyped in an applied research environment and represents a next generation assurance tool for system and network security.

13.3.28 Force Protection Joint Experiment (FPJE) Battlefield Anti-Intrusion System (BAIS) sensors data analysis and filtering metrics

C.M Barngrover, R T Laird, T A Kramer, J R Cruickshanks och S H Cutler. Proc. SPIE, Vol. 7345, 73450I (2009).

The FPJE was an experiment to consider the best way to develop and evaluate a system of systems approach to Force Protection. It was sponsored by Physical Security Equipment Action Group (PSEAG) and Joint Program Manager - Guardian (JPM-G), and was managed by the Product Manager - Force Protection Systems (PM-FPS). The experiment was an effort to utilize existing technical solutions from all branches of the military in order to provide more efficient and effective force protection. The FPJE consisted of four separate Integration Assessments (IA), which were intended as opportunities to assess the status of integration, automation and fusion efforts, and the effectiveness of the current configuration and "system" components. The underlying goal of the FPJE was to increase integration, automation, and fusion of the many different sensors and their data to provide enhanced situational awareness and a common operational picture. One such sensor system is the Battlefield Anti-Intrusion System (BAIS), which is a system of seismic and acoustic unmanned ground sensors. These sensors were originally designed for employment by infantry soldiers at the platoon level to provide early warning of personnel and vehicle intrusion in austere environments. However, when employed around airfields and high traffic areas, the sensitivity of these sensors can cause an excessive number of detections. During the second FPJE-IA all of the BAIS detections and the locations of all Opposing Forces were logged and analyzed to determine the accuracy rate of the sensors. This analysis revealed that with minimal filtering of detections, the number of false positives and false negatives could be reduced substantially to manageable levels while using the sensors within extreme operational acoustic and seismic noise conditions that are beyond the design requirements.

13.3.29 Target tracking for randomly varying number of targets and sensors using random finite set theory

A M Ali, R E Hudson och K Yao. Proc. SPIE, Vol. 7345, 73450L (2009).

Variation in the number of targets and sensors needs to be addressed in any realistic sensor system. Targets may come in or out of a region or may suddenly stop emitting detectable

signal. Sensors can be subject to failure for many reasons. We derive a tracking algorithm with a model that includes these variations using Random Finite Set Theory (RFST). RFST is a generalization of standard probability theory into the finite set theory domain. This generalization does come with additional mathematical complexity. However, many of the manipulations in RSFT are similar in behavior and intuition to those of standard probability theory.

13.3.30 Field-based data collection techniques for the evaluation of information fusion systems

B. Antonishek, B A Weiss och C Schlenoff. Proc. SPIE, Vol. 7345, 73450M (2009).

In order to effectively evaluate information fusion systems or emerging technologies, it is critical to quickly, efficient, and accurately collect functional and observational data about such systems. One of the best ways to test a system's capabilities is to have an end user operate it in controlled but realistic field-based situations. Evaluation data of the systems' performance as well as observational data of the user's interactions can then be collected and analyzed. This analysis often gives insight into how the system may perform in the intended environment and of any potential areas for improvement. One common method for collection of this data involves an evaluator/observer generating hand-written notes, comments, and sketches. This often proves to be inefficient in complex sensor technology field-based evaluation environments. Personnel at the National Institute of Standards and Technology (NIST) have been tasked with collecting such evaluation data for emerging soldier-worn sensor systems. Lessons learned from the on-going development of efficient field-based evaluation data collection techniques will be discussed. The most recent evaluation data collection using a personal digital assistant (PDA)-style system and details of its use during an evaluation of a multi-team study will also be described.

13.3.31 Recommendation-based geovisualization support for reconstitution in critical infrastructure protection

D C Wilson, O Pala, W J Tolone och W-N Xiang. Proc. SPIE, Vol. 7346, 734602 (2009).

Protecting critical infrastructure systems, such as electrical power grids, has become a primary concern for many governments and organizations across a variety of stakeholder perspectives. Critical infrastructures involve multidimensional, highly complex collections of technologies, processes, and people, and as such, are vulnerable to potentially catastrophic failures on many levels. Moreover, cross-infrastructure dependencies can give rise to cascading effects with escalating impact across multiple infrastructures. Critical infrastructure protection involves both safeguarding against potential disaster scenarios and effective response in the aftermath of infrastructure failure. Our research is developing innovative approaches to modeling critical infrastructures in order to support decision-making during reconstitution efforts in response to infrastructure disruptions. By modeling the impact of infrastructure elements, both within and across infrastructures, we can recommend focus areas for reconstitution resources across different stakeholders in the context of their current goals. An interactive geovisualization interface provides a natural context for this infrastructure analysis support. This paper presents an overview of our approach and the GIS modeling environment under development for decision support in critical infrastructure reconstitution.

13.3.32 Visual analytics for law enforcement: deploying a service-oriented analytic framework for web-based visualization

S T Dowson, J Bruce, D M Best, R M Riensche, L Franklin och W A Pike. Proc. SPIE, Vol. 7346, 734603 (2009).

This paper presents key components of the Law Enforcement Information Framework (LEIF), an information system that provides communications, situational awareness, and visual analytics tools in a service-oriented architecture supporting web-based desktop and handheld device users. LEIF simplifies interfaces and visualizations of wellestablished visual analytic techniques to improve usability. Advanced analytics capability is maintained by enhancing the underlying processing to support the new interface. LEIF development is driven by real-world user feedback gathered through deployments at three operational law enforcement organizations in the U.S. The system incorporates a robust information ingest pipeline supporting a wide variety of information formats. LEIF also insulates interface and analytical components from information sources making it easier to adapt the framework for many different data repositories.

13.3.33 Analyzing networks of static and dynamic geospatial entities for urban situational awareness

D Sherrill, M Yee och P Cho. Proc. SPIE, Vol. 7346, 734605 (2009).

Motivated by the problem of uncovering networks of illicit actors in complex urban environments, we present a prototype system for intuitive navigation of vehicle track data via interacting map and network views. Our system combines 3D geospatial visualization, social network display and interactive track search software, and it provides a multi-touch interface for operators to navigate urban scenes and investigate potentially suspicious vehicle activity. We describe a case study to highlight the system's capabilities using ground truth vehicle data collected during a 2007 urban exercise. This data is most naturally viewed as tracks in space and time. But as cluttered track displays obscure potentially important actor relationships, our system provides a social network picture whose condensed format is easier to interpret. Through coordinated space-time/vehicle network searches, we demonstrate how analysts can uncover "Red" activities of tactical significance.

13.3.34 VISAD: an interactive and visual analytical tool for the detection of behavioral anomalies in maritime traffic data

M Riveiro, G Falkman, T Ziemke och H Warston. Proc. SPIE, Vol. 7346, 734607 (2009).

Monitoring the surveillance of large sea areas normally involves the analysis of huge quantities of heterogeneous data from multiple sources (radars, cameras, automatic identification systems, reports, etc.). The rapid identification of anomalous behavior or any threat activity in the data is an important objective for enabling homeland security. While it is worth acknowledging that many existing mining applications support identification of anomalous behavior, autonomous anomaly detection systems are rarely used in the real world. There are two main reasons: (1) the detection of anomalous behavior is normally not a well-defined and structured problem and therefore, automatic data mining approaches do not work well and (2) the difficulties that these systems have regarding the representation and

employment of the prior knowledge that the users bring to their tasks. In order to overcome these limitations, we believe that human involvement in the entire discovery process is crucial. Using a visual analytics process model as a framework, we present VISAD: an interactive, visual knowledge discovery tool for supporting the detection and identification of anomalous behavior in maritime traffic data. VISAD supports the insertion of human expert knowledge in (1) the preparation of the system, (2) the establishment of the normal picture and (3) in the actual detection of rare events. For each of these three modules, VISAD implements different layers of data mining, visualization and interaction techniques. Thus, the detection procedure becomes transparent to the user, which increases his/her confidence and trust in the system and overall, in the whole discovery process.

13.3.35 Reasoning about anomalies: a study of the analytical process of detecting and identifying anomalous behavior in maritime traffic data

M Riveiro, G Falkman, T Ziemke och T Kronhamn. Proc. SPIE, Vol. 7346, 73460A (2009).

The goal of visual analytical tools is to support the analytical reasoning process, maximizing human perceptual, understanding and reasoning capabilities in complex and dynamic situations. Visual analytics software must be built upon an understanding of the reasoning process, since it must provide appropriate interactions that allow a true discourse with the information. In order to deepen our understanding of the human analytical process and guide developers in the creation of more efficient anomaly detection systems, this paper investigates how is the human analytical process of detecting and identifying anomalous behavior in maritime traffic data. The main focus of this work is to capture the entire analysis process that an analyst goes through, from the raw data to the detection and identification of anomalous behavior. Three different sources are used in this study: a literature survey of the science of analytical reasoning, requirements specified by experts from organizations with interest in port security and user field studies conducted in different marine surveillance control centers. Furthermore, this study elaborates on how to support the human analytical process using data mining, visualization and interaction methods. The contribution of this paper is twofold: (1) within visual analytics, contribute to the science of analytical reasoning with practical understanding of users tasks in order to develop a taxonomy of interactions that support the analytical reasoning process and (2) within anomaly detection, facilitate the design of future anomaly detector systems when fully automatic approaches are not viable and human participation is needed.

13.3.36 Visualization as integration of heterogeneous processes

X Wang, W Dou, W Ribarsky och R Chang. Proc. SPIE, Vol. 7346, 73460B (2009).

In the information age today, we are experiencing an explosion of data and information from a variety of sources unlike anything that the world has seen before. While technology has advanced to keep up with the collection and storage of data, what we lack now is the ability to analyze and understand the meaning behind the data. Traditionally, data mining and data management techniques require the data to be uniform such that a single process can search for knowledge within the data. However, in analysis of complex tasks where knowledge and information need to be pieced together from different sources of data, a new paradigm is required. In this paper, we present a framework of using visual analytical approaches to integrate multiple heterogeneous processes that can each analyze a specific type of data. Under

this framework, stand-alone software solutions can focus on specific aspects of the problem based on domain-specific techniques. The framework serves as a visual repository for all the information and knowledge discovered by each individual process, and allows the user to interactively perform sense-making analysis to form a cohesive and comprehensive understanding of the problem at hand. We demonstrate the effectiveness of this framework by applying it to inspecting bridge conditions that utilizes data sources from 2D imagery, 3D LiDAR, and multi-dimensional data based on bridge reports.

13.3.37 Integrating time-series visualizations within parallel coordinates for exploratory analysis of incident databases

M Butkiewicz, T Butkiewicz, W Ribarsky och R Chang. Proc. SPIE, Vol. 7346, 73460C (2009).

Aviation disaster prevention has always been of interest to homeland security, especially after the recent use of aircrafts as weapons by terrorists. With better understanding of the deficiency of different types of aircraft and their corresponding effects on the craft's safety, better maintenance and response plans can be devised to prevent disasters from occurring. In this paper, we present a visual analytical technique to examine the Federal Aviation Agency's Accident/Incident Database, which contains more than 90,000 incidents across 53 dimensions over the last 30 years, for identifying trends of relationships between dimensions over time. Our technique is based on the integration of the ThemeRiver technique directly within a parallel coordinates framework, and simultaneously presents both a "forward flow view" and a "backward flow view" between each dimension. The forward flow view shows the trends over time of each of the elements-of-interest in the first dimension, while the backward flow view illustrates how the elements in the second dimension contribute to the overall trends seen in the first dimension. Through the use of our technique, we were able to identify characteristics of aircrafts and suggest plausible explanations to their common failures.

13.3.38 Hierarchical multi-touch selection techniques for collaborative geospatial analysis

T Butkiewicz, D H Jeong, Z Wartell, W Ribarsky och R Chang. Proc. SPIE, Vol. 7346, 73460D (2009).

In time critical visual analytic environments collaboration between multiple expert users allows for rapid knowledge discovery and facilitates the sharing of insight. New collaborative display technologies, such as multi-touch tables, have shown great promise as the medium for such collaborations to take place. However, under such new technologies, traditional selection techniques, having been developed for mouse and keyboard interfaces, become inconvenient, inefficient, and in some cases, obsolete. We present selection techniques for multi-touch environments that allow for the natural and efficient selection of complex regions-of-interest within a hierarchical geospatial environment, as well as methods for refining and organizing these selections. The intuitive nature of the touch-based interaction permits new users to quickly grasp complex controls, while the consideration for collaboration coordinates the actions of multiple users simultaneously within the same environment. As an example, we apply our simple gestures and actions mimicking real-world tactile behaviors to increase the usefulness and efficacy of an existing urban growth simulation in a traditional GIS-like environment. However, our techniques are general enough to be applied across a wide range of geospatial analytical applications for both domestic security and military use.

13.3.39 Human behavior digitization and intent recognition using data modeling

H M Jaenisch, J W Handley, K L Jaenisch och N G Albritton. Proc. SPIE, Vol. 7346, 73460E (2009).

Autonomous and network centric smart cameras for use in homeland security and other human activities monitoring applications require a multi-layer approach for real time image processing. We propose a novel method to achieve behavior digitization and preemptive course of action (COA) analysis by converting temporal and spatial pixel subframes into a form that can be encoded into equation based Data Models. Output from these Data Models is fused with evidence and sensor data in the COA decision cascade, which recommends COAs that yield evidence. Evidence from the decision cascade continues to be amassed until the hypothesized threat forms a strong enough conviction to initiate alert responses and external intercepting events. This paper outlines our proposed methodology and approach.

13.4 Artiklar från SPIE Defence and Security 2010

Ordnat efter volyms- och artikelnummer.

13.4.1 Hypergame theory applied to cyber attack and defense

J T House och G Cybenko. Proc. SPIE, Vol. 7666, 766604 (2010).

This work concerns cyber attack and defense in the context of game theory—specifically hypergame theory. Hypergame theory extends classical game theory with the ability to deal with differences in players' expertise, differences in their understanding of game rules, misperceptions, and so forth. Each of these different sub-scenarios, or subgames, is associated with a probability—representing the likelihood that the given subgame is truly "in play" at a given moment. In order to form an optimal attack or defense policy, these probabilities must be learned if they're not known a-priori. We present hidden Markov model and maximum entropy approaches for accurately learning these probabilities through multiple iterations of both normal and modified game play. We also give a widely-applicable approach for the analysis of cases where an opponent is aware that he is being studied, and intentionally plays to spoil the process of learning and thereby obfuscate his attributes. These are considered in the context of a generic, abstract cyber attack example. We demonstrate that machine learning efficacy can be heavily dependent on the goals and styles of participant behavior. To this end detailed simulation results under various combinations of attacker and defender behaviors are presented and analyzed.

13.4.2 Using principal component analysis for selecting network behavioral anomaly metrics

I Gregorio-de Souza, V Berk och A Barsamian. Proc. SPIE, Vol. 7666, 766605 (2010).

This work addresses new approaches to behavioral analysis of networks and hosts for the purposes of security monitoring and anomaly detection. Most commonly used approaches simply implement anomaly detectors for one, or a few, simple metrics and those metrics can

exhibit unacceptable false alarm rates. For instance, the anomaly score of network communication is defined as the reciprocal of the likelihood that a given host uses a particular protocol (or destination);this definition may result in an unrealistically high threshold for alerting to avoid being flooded by false positives. We demonstrate that selecting and adapting the metrics and thresholds, on a host-by-host or protocol-by-protocol basis can be done by established multivariate analyses such as PCA. We will show how to determine one or more metrics, for each network host, that records the highest available amount of information regarding the baseline behavior, and shows relevant deviances reliably. We describe the methodology used to pick from a large selection of available metrics, and illustrate a method for comparing the resulting classifiers. Using our approach we are able to reduce the resources required to properly identify misbehaving hosts, protocols, or networks, by dedicating system resources to only those metrics that actually matter in detecting network deviations

13.4.3 Dynamic social network analysis using conversational dynamics in social networking and microblogging environments

G Stocco, R Savell och G Cybenko. Proc. SPIE, Vol. 7666, 766606 (2010).

In many security environments, the textual content of communications may be unavailable. In these instances, it is often desirable to infer the status of the network and its component entities from patterns of communication flow. Conversational dynamics among entities in the network may provide insight into important aspects of the underlying social network such as the formational dynamics of group structures, the active state of these groups, individuals' roles within groups, and the likelihood of individual participation in conversations. To gain insight into the use of conversational dynamics to facilitate Dynamic Social Network Analysis, we explore the use of interevent timings to associate entities in the Twitter social networking and micro-blogging environment. Specifically, we use message timings to establish inter-nodal relationships among participants. In addition, we demonstrate a new visualization technique for tracking levels of coordination or synchronization within the community via measures of socio-temporal coherence of the participants.

13.4.4 A Bayesian belief network of threat anticipation and terrorist motivations

M M Olama, G O Allgood, K M Davenport, och J C Schryver. Proc. SPIE, Vol. 7666, 76660V (2010).

Recent events highlight the need for efficient tools for anticipating the threat posed by terrorists, whether individual or groups. Antiterrorism includes fostering awareness of potential threats, deterring aggressors, developing security measures, planning for future events, halting an event in process, and ultimately mitigating and managing the consequences of an event. To analyze such components, one must understand various aspects of threat elements like physical assets and their economic and social impacts. To this aim, we developed a three-layer Bayesian belief network (BBN) model that takes into consideration the relative threat of an attack against a particular asset (physical layer) as well as the individual psychology and motivations that would induce a person to either act alone or join a terrorist group and commit terrorist acts (social and economic layers). After researching the many possible motivations to become a terrorist, the main factors are compiled and sorted into categories such as initial and personal indicators, exclusion factors, and predictive behaviors.

Assessing such threats requires combining information from disparate data sources most of which involve uncertainties. BBN combines these data in a coherent, analytically defensible, and understandable manner. The developed BBN model takes into consideration the likelihood and consequence of a threat in order to draw inferences about the risk of a terrorist attack so that mitigation efforts can be optimally deployed. The model is constructed using a network engineering process that treats the probability distributions of all the BBN nodes within the broader context of the system development process.

13.4.5 The emerging role of global situational awareness 2.0 resources in disaster response

C Taylor. Proc. SPIE, Vol. 7666, 766613 (2010).

Public Health organizations throughout the world are called upon to be at the forefront of responding to emerging infectious disease events or natural catastrophes such as the Haitian and Chilean earthquakes. One of the key components to effective public health engagement is situational awareness. Situational awareness means understanding what is going on around you. Whilst that may seem to be a simple statement it is not. True situational awareness means acquiring all relevant information about the event and translating that information into actionable knowledge.

13.4.6 Behavioral analysis of loosely coupled systems

N F Sandell och G V Cybenko. Proc. SPIE, Vol. 7666, 76661M (2010).

Techniques for dynamic behavioral analysis and modeling have recently become an increasingly researched topic. In essence, they aim to understand the mechanics of a set of variables over time, allowing for prediction of future data, anomaly or change detection, or estimation of a latent variable. Much of this research has focused on the sequential analysis of individual tracks of data - for example, in multi-target tracking (MTT). In recent years, massive amounts of behavioral and usage data have become available due to the proliferation of online services and their large users bases. The data from these applications can not be said to be monolithically generated - there are many processes and activities occurring simultaneously. However, it also cannot be said that this data consists of a set of independently running processes, as there are often strong correlations among subsets of the variables. Therefore we have a potentially large set of loosely coupled entities that can be modeled neither as a single, large process, or a large set of individual processes. "Static" applications, e.g. rating predictors for recommender systems, have greatly exploited entity to entity correlations through processes such as collaborative filtering. In this paper, we present a probabilistic model for loosely coupled and correlated dynamic data sets and techniques for making inference about the model. Experimental results are presented using data gathered from instrumented wireless access points around a college campus.

13.4.7 Homeland security application of the Army Soft Target Exploitation and Fusion (STEF) system

R T Antony och J A Karakowski. Proc. SPIE, Vol. 7666, 76661O (2010).

A fusion system that accommodates both text-based extracted information along with more conventional sensor-derived input has been developed and demonstrated in a terrorist attack

scenario as part of the Empire Challenge (EC) 09 Exercise. Although the fusion system was developed to support Army military analysts, the system, based on a set of foundational fusion principles, has direct applicability to department of homeland security (DHS) & defense, law enforcement, and other applications. Several novel fusion technologies and applications were demonstrated in EC09. One such technology is location normalization that accommodates both fuzzy semantic expressions such as behind Library A, across the street from the market place, as well as traditional spatial representations. Additionally, the fusion system provides a range of fusion products not supported by traditional fusion algorithms. Many of these additional capabilities have direct applicability to DHS. A formal test of the fusion system was performed during the EC09 exercise. The system demonstrated that it was able to (1) automatically form tracks, (2) help analysts visualize behavior of individuals over time, (3) link key individuals based on both explicit message-based information as well as discovered (fusion-derived) implicit relationships, and (4) suggest possible individuals of interest based on their association with High Value Individuals (HVI) and user-defined key locations.

13.4.8 Sensor and information fusion for improved hostile fire situational awareness

M V Scanlon och W D Ludwig. Proc. SPIE, Vol. 7693, 76930H (2010).

A research-oriented Army Technology Objective (ATO) named Sensor and Information Fusion for Improved Hostile Fire Situational Awareness uniquely focuses on the underpinning technologies to detect and defeat any hostile threat; before, during, and after its occurrence. This is a joint effort led by the Army Research Laboratory, with the Armaments and the Communications and Electronics Research, Development, and Engineering Centers (CERDEC and ARDEC) partners. It addresses distributed sensor fusion and collaborative situational awareness enhancements, focusing on the underpinning technologies to detect/identify potential hostile shooters prior to firing a shot and to detect/classify/locate the firing point of hostile small arms, mortars, rockets, RPGs, and missiles after the first shot. A field experiment conducted addressed not only diverse modality sensor performance and sensor fusion benefits, but gathered useful data to develop and demonstrate the ad hoc networking and dissemination of relevant data and actionable intelligence. Represented at this field experiment were various sensor platforms such as UGS, soldier-worn, manned ground vehicles, UGVs, UAVs, and helicopters. This ATO continues to evaluate applicable technologies to include retro-reflection, UV, IR, visible, glint, LADAR, radar, acoustic, seismic, E-field, narrow-band emission and image processing techniques to detect the threats with very high confidence. Networked fusion of multi-modal data will reduce false alarms and improve actionable intelligence by distributing grid coordinates, detection report features, and imagery of threats.

13.4.9 Aspects of sensor data fusion in interoperable ISR systems of systems for wide-area ground surveillance

W Koch, M Ulmke, J Biermann och M Sielemann. Proc. SPIE, Vol. 7694, 769405 (2010).

Within the context of C4ISTAR information "systems of systems", we discuss sensor data fusion aspects that are aiming at the generation of higher-level in-formation according to the JDL model of data fusion. In particular, two issues are addressed: (1) Tracking-derived Situation Elements: Standard target tracking applications gain information related to 'Level 1 Fusion' according to the well-established terminology of the JDL model. Kinematic data of this type, however, are by no means the only information to be derived from tar-get tracks. In

many cases, reliable and quantitative higher level information according to the JDL terminology can be obtained. (2) Anomaly Detection in Tracking Data Bases: Anomaly detection can be regarded as a process of information fusion that aims at focusing the attention of human decision makers or decision making systems is focused on particular events that are "irregular" or may cause harm and thus require special actions.

13.4.10 Exact particle flow for nonlinear filters

F Daum, J Huang och A Noushin. Proc. SPIE, Vol. 7697, 769704 (2010).

We have invented a new theory of exact particle flow for nonlinear filters. This generalizes our theory of particle flow that is already many orders of magnitude faster than standard particle filters and which is several orders of magnitude more accurate than the extended Kalman filter for difficult nonlinear problems. The new theory generalizes our recent log-homotopy particle flow filters in three ways: (1) the particle flow corresponds to the exact flow of the conditional probability density; (2) roughly speaking, the old theory was based on incompressible flow (like subsonic flight in air), whereas the new theory allows compressible flow (like supersonic flight in air); (3) the old theory suffers from obstruction of particle flow as well as singularities in the equations for flow, whereas the new theory has no obstructions and no singularities. Moreover, our basic filter theory is a radical departure from all other particle filters in three ways: (a) we do not use any proposal density; (b) we never resample; and (c) we compute Bayes' rule by particle flow rather than as a point wise multiplication.

13.4.11 A fresh perspective on research for nonlinear filters

F Daum och J Huang. Proc. SPIE, Vol. 7697, 769705 (2010).

We give a fresh perspective on research for nonlinear filters with particle flow. Such research is an interesting mixture of theory and numerical experiments, as well as tradeoffs in filter implementation using GPUs and fast approximate k-NN algorithms, and fast approximate Poisson solvers. Our fundamental idea is to compute Bayes' rule using an ordinary differential equation (ODE) rather than a pointwise multiplication; this solves the problem of particle degeneracy. Our filter is many orders of magnitude faster than standard particle filters for high dimensional problems, and it is several orders of magnitude more accurate than the EKF for difficult nonlinear problems, including problems with multimodal densities.

13.4.12 A study of nonlinear filters with particle flow induced by log-homotopy

L Chen och R K Mehra. Proc. SPIE, Vol. 7697, 769706 (2010).

In this paper, a study of the particle flow filter proposed by Daum and Huang has been conducted. It is discovered that for certain initial conditions, the desired particle flow that brings one particle from a good location in the prior distribution to a good location in the posterior distribution with an equal value does not exist. This explains the phenomenon of outliers experienced by Daum and Huang. Several ways of dealing with the singularity of the gradient have been discussed, including (1) not moving the particles without a flow solution, (2) stopping the flow entirely when it approaches the singularity, and (3) stopping for one step and starting in the next. In each case the resulting set of particles are examined, and it is doubtful that they form a valid set of samples for the approximation of the desired posterior

distribution. In the case of the last method (stop and go), the particles mostly concentrate on the mode of the desired distribution (but they fail to represent the whole distribution), which may explain the "success" reported in the literature so far. An established method of moving particles, the well known Population Monte Carlo method, is briefly presented in this paper for ease of reference.

13.4.13 Feynman path integrals and continuous nonlinear filtering

B Balaji. Proc. SPIE, Vol. 7697, 769707 (2010).

Recently, it has been shown that the continuous-discrete and continuous-continuous nonlinear filtering problems can be formulated and solved in terms of Feynman path integrals. A physical and conceptual explanation of the central results is presented. The major role played by such techniques in modern theoretical physics and pure mathematics is briefly reviewed. Several advantages of the proposed formulation (over other approaches in standard filtering theory literature) are discussed. Also clarified are the origin of some filtering theory results, such as the Yau algorithm for continuous-continuous filtering, and the relation between certain nonlinear filering systems and Euclidean quantum physics.

13.4.14 Feynman path integral inspired computational methods for nonlinear filtering

B Balaji. Proc. SPIE, Vol. 7697, 769708 (2010).

The fundamental solution for the continuous-time filtering problems can be expressed in terms of Feynman path integrals. This enables one to view the solution of filtering problem in terms of an effective action that is a function of the signal and measurement models. The practical utility of the path integral formula is demonstrated via some nontrivial examples. Specifically, it is shown that the simplest approximation of the path integral formula for the fundamental solution of the Fokker-Planck-Kolmogorov forward equation (termed the Dirac-Feynman approximation) can be applied to solve nonlinear continuous-discrete filtering problems quite accurately using sparse grid filtering and Monte-Carlo approaches.

13.4.15 Game theoretic sensor management for target tracking

D Shen, G Chen, E Blasch, K Pham, P Douville, C Yang och I Kadar. Proc. SPIE, Vol. 7697, 76970C (2010).

This paper develops and evaluates a game-theoretic approach to distributed sensor-network management for target tracking via sensor-based negotiation. We present a distributed sensor-based negotiation game model for sensor management for multi-sensor multi-target tacking situations. In our negotiation framework, each negotiation agent represents a sensor and each sensor maximizes their utility using a game approach. The greediness of each sensor is limited by the fact that the sensor-to-target assignment efficiency will decrease if too many sensor resources are assigned to a same target. It is similar to the market concept in real world, such as agreements between buyers and sellers in an auction market. Sensors are willing to switch targets so that they can obtain their highest utility and the most efficient way of applying their resources. Our sub-game perfect equilibrium-based negotiation strategies dynamically and

distributedly assign sensors to targets. Numerical simulations are performed to demonstrate our sensor-based negotiation approach for distributed sensor management.

13.4.16 PHD filtering in known target-dependent clutter

R Mahler och A El-Fallah. Proc. SPIE, Vol. 7697, 76970E (2010).

This paper generalizes the PHD filter to the case of target-dependent clutter. It is assumed that a distinct a priori Poisson clutter process is associated with each target. Multitarget calculus techniques are used to derive formulas for the measurement-update step. These formulas require combinatorial sums over all partitions of the current measurement-set. Further research is required to address the resulting computational issues.

13.4.17 CPHD filtering with unknown probability of detection

R Mahler och A El-Fallah. Proc. SPIE, Vol. 7697, 76970F (2010).

The conventional PHD and CPHD filters presume that the probability $pD(x)$ that a measurement will be collected from a target with state-vector x (the state-dependent probability of detection) is known a priori. However, in many applications this presumption is false. A few methods have been devised for estimating the probability of detection, but they typically presume that $pD(x)$ is constant in both time and the region of interest. This paper introduces CPHD/PHD filters that are capable of multitarget track-before-detect operation even when probability of detection is not known and, moreover, when it is not necessarily constant, either temporally or spatially. Furthermore, these filters are potentially computationally tractable. We begin by deriving CPHD/PHD filter equations for the case when probability of detection is unknown but the clutter model is known a priori. Then, building on the results of a companion paper, we note that CPHD/PHD filters can be derived for the case when neither probability of detection or the background clutter are known.

13.4.18 Direct message passing for hybrid Bayesian networks and performance analysis

W Sun och K C Chang. Proc. SPIE, Vol. 7697, 76970S (2010).

Probabilistic inference for hybrid Bayesian networks, which involves both discrete and continuous variables, has been an important research topic over the recent years. This is not only because a number of efficient inference algorithms have been developed and used maturely for simple types of networks such as pure discrete model, but also for the practical needs that continuous variables are inevitable in modeling complex systems. Pearl's message passing algorithm provides a simple framework to compute posterior distribution by propagating messages between nodes and can provides exact answer for polytree models with pure discrete or continuous variables. In addition, applying Pearl's message passing to network with loops usually converges and results in good approximation. However, for hybrid model, there is a need of a general message passing algorithm between different types of variables. In this paper, we develop a method called Direct Message Passing (DMP) for exchanging messages between discrete and continuous variables. Based on Pearl's algorithm, we derive formulae to compute messages for variables in various dependence relationships encoded in conditional probability distributions. Mixture of Gaussian is used to represent continuous messages, with the number of mixture components up to the size of the joint state space of all

discrete parents. For polytree Conditional Linear Gaussian (CLG) Bayesian network, DMP has the same computational requirements and can provide exact solution as the one obtained by the Junction Tree (JT) algorithm. However, while JT can only work for the CLG model, DMP can be applied for general nonlinear, non-Gaussian hybrid model to produce approximate solution using unscented transformation and loopy propagation. Furthermore, we can scale the algorithm by restricting the number of mixture components in the messages. Empirically, we found that the approximation errors are relatively small especially for nodes that are far away from the discrete parent nodes. Numerical simulations show encouraging results.

13.4.19 Human-centered information fusion: the emerging role of humans in situation awareness

D L Hall. Proc. SPIE, Vol. 7709, 770903 (2010).

Traditionally, information or data fusion has sought to combine information from multiple physical sensors, such as radar and acoustic sensors, to improve our knowledge of the physical environment. Recent changes in information fusion involve; (1) an interest in characterizing the human landscape as well as the physical landscape, (2) use of humans as observers or "soft" sensors, (3) explicit use of human pattern recognition via advanced visualization and sonficiation, and (4) use of multiple humans for dynamic, ad hoc, collaboration for analysis. This paper describes these new trends and describes on-going research at the Pennsylvania State University in all of these areas.

13.4.20 Evaluation of current visualization tools for cyber security

J T Langton och B Newey. Proc. SPIE, Vol. 7709, 770910 (2010).

Visualization tools for cyber security often overlook related research from the information visualization domain. Cyber security data sets are notoriously large, yet many of the popular analysis tools use 3D techniques and parallel coordinates which have been shown to suffer issues of occlusion when applied to large data sets[1,2]. While techniques exist to ameliorate these issues they are typically not used. In this paper we evaluate several cyber security visualization tools based on established design principles and human-computer interaction research. We conclude by enumerating challenges, requirements, and recommendations for future work.

13.4.21 Visualization for cyber security command and control

J T Langton och B Newey. Proc. SPIE, Vol. 7709, 770911 (2010).

To address the unique requirements of cyber Command and Control (C2), new visualization methods are needed to provide situation awareness and decision support within the cyber domain. A key challenge is the complexity of relevant data: it is immense and multidimensional, includes streaming and log data, and comes from multiple, disparate applications and devices. Decision makers must be afforded a view of a) the current state of the cyber battlespace, b) enemy and friendly capabilities and vulnerabilities, c) correlations between cyber events, and d) potential effects of alternative courses of action within cyberspace. In this paper we present requirements and designs for Visualization for Integrated Cyber Command and Control (VIC3).

13.4.22 Dynamic 3D visual analytic tools: a method for maintaining situational awareness during high tempo warfare or mass casualty operations

T E. Lizotte. Proc. SPIE, Vol. 7709, 770912 (2010).

Maintaining Situational Awareness (SA) is crucial to the success of high tempo operations, such as war fighting and mass casualty events (bioterrorism, natural disasters). Modern computer and software applications attempt to provide command and control manager's situational awareness via the collection, integration, interrogation and display of vast amounts of analytic data in real-time from a multitude of data sources and formats [1]. At what point does the data volume and displays begin to erode the hierarchical distributive intelligence, command and control structure of the operation taking place? In many cases, people tasked with making decisions, have insufficient experience in SA of high tempo operations and become overwhelmed easily as vast amounts of data begin to be displayed in real-time as an operation unfolds. In these situations, where data is plentiful and the relevance of the data changes rapidly, there is a chance for individuals to target fixate on those data sources they are most familiar. If these individuals fall into this type of pitfall, they will exclude other data that might be just as important to the success of the operation. To counter these issues, it is important that the computer and software applications provide a means for prompting its users to take notice of adverse conditions or trends that are critical to the operation. This paper will discuss a new method of displaying data called a Crisis View^{TM}, that monitors critical variables that are dynamically changing and allows preset thresholds to be created to prompt the user when decisions need to be made and when adverse or positive trends are detected. The new method will be explained in basic terms, with examples of its attributes and how it can be implemented.

13.4.23 Incorporating time and spatial-temporal reasoning into situation management

G Jakobson. Proc. SPIE, Vol. 7709, 77090H (2010).

Spatio-temporal reasoning plays a significant role in situation management that is performed by intelligent agents (human or machine) by affecting how the situations are recognized, interpreted, acted upon or predicted. Many definitions and formalisms for the notion of spatio-temporal reasoning have emerged in various research fields including psychology, economics and computer science (computational linguistics, data management, control theory, artificial intelligence and others). In this paper we examine the role of spatio-temporal reasoning in situation management, particularly how to resolve situations that are described by using spatio-temporal relations among events and situations. We discuss a model for describing context sensitive temporal relations and show have the model can be extended for spatial relations.

13.5   Artiklar från International Command and Control Research and Technology Symposium (ICCRTS) 2010

Ordnat alfabetiskt efter titel.

13.5.1 A mixed-initiative advisory system for threat evaluation

H Irandoust, A Benaskeur och F. Kabanza, ICCRTS 2010

Threat evaluation in naval Anti-Air Warfare (AAW) operations is accompanied by an unprecedented level of stress and cognitive overload for the operators mainly because of the dynamic and time-constrained nature of the context and the important amount of variables involved. A mixed-initiative capability is proposed that provides the operator with the needed information at different steps of his problem-solving task. Recognizing assistance opportunities, the capability provides, opportunistically, feedback that is adapted to the current problem-solving situation. Exploiting threat evaluation algorithms, the capability reasons on several inputs, such as the operator's actions and preferences; the automation solution and its characteristics; and contextual information, in order to plan the best feedback in terms of content, format, and timing. While relieving the operator's memory resources by representing the problem space through graphical interfaces, the capability uses several strategies to draw his/her attention on missing data, to highlight relevant (and sometimes overlooked) information, and to signal reasoning flaws. The proposed capability not only supports in this way the operator in his own inferential process, but is also capable of explaining and putting forth arguments in favour of its solutions in order to build the operator's trust in its recommendations.

13.5.2 Hypothesis Management in Support of Inferential Reasoning

R Haberlin, P C G da Costa och K B Laskey, ICCRTS 2010

A key component of Maritime Domain Awareness (MDA), situational awareness supports tactical decision making through fusion of intelligence, geography, environment, and the geopolitical situation. Advanced decision support systems will provide the decision maker with a number of hypotheses from which the evolving situation may be inferred, limited by the computational capacity of today's computer hardware. In this context, a hypothesis can be thought of as a statement of anticipated action in which an actor will conduct an action against a target with a location, time and methodology of his choosing. Hypothesis Management is the control of exponential growth in fusion hypotheses created by incoming data reports, without which the computational capability of hardware is quickly overwhelmed. This paper explores our research on Hypothesis Management techniques in support of inferential reasoning. More specifically, we focus on managing the creation, modification, administration, storage and movement of hypotheses to ensure that only attributes and entities relative to the current context are presented for inferential reasoning. Our approach supports recognition of observed trends and is capable of creating original hypothesis through innovative transformations of existing hypotheses, providing the decision maker with asymmetrical scenario possibilities gleaned from observed attribute data and stored hypothesis histories.

13.5.3 Maritime Domain Awareness via Agent Learning and Collaboration

Y Zhao et al, ICCRTS 2010

Maritime security is vital to US security. Enhanced Maritime Domain Awareness (MDA) of potential threats in this dynamic environment can be achieved, yet requires integrated analysis from numerous sources in real time. We will present a learning agent technology that

integrates structured and unstructured data and discovers behavior patterns from varied sources such as: Automatic Information Systems (AIS), Coast Guard, and police contextual information including: maritime commercial activities, weather, terrain, environmental conditions, maritime incidents, casualties, and military exercises. These discovered patterns can help correlate warnings and reduce false alarms in support of maritime security. We will show our test results from the Trident Warrior (TW08) exercise.

We will also discuss the agent learning applied to system self-awareness, where we consider that the cognitive interface between decision makers and a complex system may be expressed in a range of terms or "features," i.e. specific vocabulary to describe a System of Systems (SoS) or so-called Lexical Link Analysis (LLA). MDA is an extremely varied and dynamic SoS, requiring constant collaboration and decision making. We will discuss prototypes of agent learning and collaboration, LLA, and visualization that provide real-time "views" of SoS to support largescale decision making for MDA technology acquisition, irregular warfare at sea, and intelligence collection with analysis automation.

13.5.4 Priority Intelligence Requirement Answering and Commercial Question-Answering: Identifying the Gaps

Ulicny et al ICCRTS 2010

Doctrinally, Priority Intelligence Requirements (PIRs) are information that the commander needs to know in order to make a decision or achieve a desired effect. Networked warfare provides the intelligence officer with access to multitudes of reports and sensor outputs. What technology can the intelligence officer use to find answers to PIRs in this sea of information? Recent developments in enterprise search technology have accelerated. To what extent can commercial search technologies assist with the task of PIR answering? In this paper, we outline doctrinal approaches to PIRs and PIR answering and explore how they have been adapted to contemporary warfare. We then explore five types of question-answering technologies: structured data technologies; unstructured textbased technologies; semistructured or "tagged text"based; logic or "semantic web" technologies; and social question-answering technologies. We identify gaps in the PIR answering process that cannot be filled by contemporary Commercial offtheshelf (COTS) solutions.

13.5.5 SKIPAL: The Incorporation of Machine Learning Technology into the Strategic Knowledge Integration Web

D S Lange et al, ICCRTS 2010

The Personalized Assistant that Learns (PAL) program was a DARPA research program with the primary goal of creating an integrated system that can adapt to changes in its environment and the users' goals and tasks without programming assistance or technical intervention. SKIWeb is an information aggregation system based at USSTRATCOM and is available to anyone on SIPRNET, a secure internet for the US Department of Defense. With a user base over twenty five thousand, and a constantly growing number of human and automated contributors, SKIWeb content threatens to overwhelm users, causing them to miss critical information amid a deluge of information. We hypothesized that PAL technology could be used to learn the information the user requires by observing the implicit and explicit signals in their interaction with SKIWeb; and that further, PAL technology could help with event identification and to expose the relationships between events and SKIWeb users, both of which could be leveraged to improve efficiency and quality in USSTRATCOM operations. Based on

experimental results, USSTRATCOM has made the required budget requests to transition SKIPAL to a program of record. This paper describes the technologies incorporated into SKIPAL, results of the experimentation, and methods that have led to both a technical and programmatic transition success.

13.6 Artiklar från NATO RTO IST-RSY-086 on C3I for Crisis, Emergency and Consequence Management, Bukarest, Maj 2009

Symposium arrangerat av NATO Research and Technology Organization, Information Systems Technology panel. Ordnat alfabetiskt efter titel.

13.6.1 A Collaborative Command Portal Environment in Support of Crisis and Emergency Situations

A-C Boury-Brisset.

Military organizations, in support of both domestic and internationally deployed operations, require enhanced information sharing, exchange and coordination between nations or government agencies. In particular, crisis or emergency management situations require a timely collective response. Significant research has been achieved for a few years to provide military decision makers and operators in command centres with information and knowledge management tools and services that help gain situation awareness, such as enterprise knowledge portals. In this paper, we describe the concepts and technologies that have been investigated as part of the JCDS 21 Technology Demonstration Project to provide military operators and decision makers with a command portal environment that supports enhanced situational awareness. To achieve this, a set of information and knowledge management services has been implemented and lays the foundation of an advanced command portal. These services have been incorporated in the web-based Command and Control Collaborative Environment (C2CE) that also integrates command and control web-based applications and is connected to external applications to support planning, monitoring of resources, and execution management.

13.6.2 A Time Sensitive Decision Support System for Crisis and Emergency Management

A Guitouni.

This paper discusses crisis and emergency management decision support based on the Joint Command Decision Support System experience. Crisis and emergency management requires a set of enablers to address the challenges of the unfolding situation under time and space constraints. The paper presents an overview of the complexity of crisis situation. Then, the requirements for an integrated decision support system are portrayed. The Defence R&D Canada technology demonstration project Joint Command Decision Support System (JCDS 21) is used to illustrate the implementation and the integration of the different decision aids investigated. JCDS 21 has addressed Canadian domestic operations management context

characterised by the multiplicity of actors and stakeholders, the diversity of the public infrastructure, the complicated legal framework, the changing lead agency based on the situation and the scarcity of response resources. Lessons learned have been deducted for further investigations.

13.6.3 Fusion and Inference in Surveillance Networks

M Rabbat och M Coates.

Networks of thousands of sensors now exist in most cities in the world. These networks continuously gather data that can be incredibly useful when a response team is evaluating the situational parameters during an emergency and formulating a strategy. But extracting the valuable information from the overwhelming abundance of data collected by the network is an extremely challenging task. This paper surveys the research objectives, methodologies and progress of the research project "Fusion and Inference in Surveillance Networks", which is sponsored by MITACS (Mathematics of Information Technology and Complex Systems), a Canadian Research Network. The non-academic partners involved in this project are Defence Research and Development Canada, CAE, and Lockheed Martin. We highlight our vision of the architecture of a city-wide surveillance network that can aid decision-making in a crisis. We discuss the progress we have made in its development and the challenges that lie before us.

13.6.4 I-BRIDGE: The Intelligent Cross-Belt Area between Authorities

VG Hoek och W M Steenis.

Homeland Security is the third main task of the Dutch Armed Forces after maintaining territorial integrity and honoring NATO commitments. The MOD is responsible for supporting civil authorities in upholding the law and in providing disaster relief and humanitarian relief wherever requested. This support is not only focused on 'manpower' but is especially based on the unique capacities and experiences that were gained during crises response operations internationally. Lots of the asymmetrical national security threats are comparable to the threats faced by the Armed Forces in their daily operations.

The Business line Public Order and Safety at IVENT is specialized in this field and has a broad and diverse range of tasks within the MOD but also within other Ministries. One of these tasks is realizing the i-Bridge 2.0 Proof-of-Concept. I-Bridge is based on a Web 2.0 and Enterprise 2.0 mindset. These concepts are relatively new ways of thinking for the government about collaboration and sharing information under less than ideal circumstances. What do you need as support for fighting crises? And how can could one harmonize all these often contradictory procedures, technologies, mandates and perspectives?

This paper informs about the i-Bridge 2.0 (Intelligent Bridge 2.0) concept: an innovative project in the field of public order and safety. The five functionalities that support the process of handling crises, Geographic Information Systems, Collaboration, Voice Interoperability, Security and Logging are combined in a kind of Mesh-up. The strength of the concept lies in the integration of these five generic functionalities into a subscription model that makes it possible to collaborate safely and secure, on ad-hoc basis and above all on a standard common desktop equipment. The innovation can be found in the fact that a traditional government approach would be to order one product to solve a specific subset of variables, rather than to create a generic marketplace for niches under a subscription model.

13.6.5 Information Evaluation as a Decision Support for Counter-Terrorism

T Delavallade och P Capet.

We present a global information management platform dedicated to open source intelligence that will be developed during a three year project funded by the French national research agency. This platform aims at providing support to intelligence analysts through the whole intelligence chain, from data collection to reasoning and decision support applications with a main focus on information evaluation. Due to the high uncertainty that surrounds open source data, information evaluation has been placed at the core of platform. Because open source intelligence has a key role to play in the fight against terrorism, this specific security issue has been considered as the focal point for the application driven tools: information seriousness assessment, social networks monitoring and information trends monitoring.

13.6.6 Information Fusion for Harbour Security through Persistent Surveillance

E Blasch, E Shahbazian, P Valin och E Bossé.

Harbour security requires attributes of detection, fusion, and intelligence to detect, prevent, and respond during crisis events. Through the development of modern sensor technology such as handheld devices, geospatial databases, and wireless communication; there is a growing interest to coordinate and disseminate information to respond to a crisis. Many traditional methods of disaster preparedness have supported emergency crews to respond to the catastrophe; however enhancements can be made through persistence surveillance and sensor technology to determine open traffic routes and cleared pathways. One of the difficulties inherent in harbour crisis response is the restricted terrain from which vehicles and supplies are available. The demarcation of the land-to-sea transition (littoral) could be a hindrance; however, with persistent surveillance to support information fusion needs, it can be a method of valid ingress of supplies and egress of people. This paper explores some of the emerging persistent surveillance techniques that could support crisis preparedness and response for a harbour environment.

13.6.7 Interoperable Sharing of Data with the Coalition Shared Data (CSD) Server

B Essendorfer och W Mueller.

In crisis management quick and full situation awareness is essential to enable adequate countermeasures and reactions. Relevant information has to be distributed to agencies and decision makers. To overcome the limitations of today's stovepiped ISR systems, interoperable transnational systems, capable of including all relevant data sources and sharing them among law enforcement bodies, are needed. To enforce the interoperability of ISR systems the multinational nine-nation intelligence and surveillance project MAJIIC (Multi-Sensor Aerospace-Ground Joint ISR Interoperability Coalition) developed standards, technologies and an architecture that allow commanders to instantly tap into real-time data from a number of NATO and national systems. Standardized data dissemination is the key in achieving interoperability. A Coalition Shared Data (CSD) server, which is based on STANAG 4559 is the core of that architecture and enables the dissemination and storage of data from heterogeneous sensors from different nations, as well as tasking information and

sensor data exploitation results. To make information available no matter where it is stored and where it is needed, the CSD concept envisions the near real-time synchronization of the metadata between different servers. The information about products in the CSD is available in the whole network, regardless of where those products are stored. Each user needs to know only one access point, his local CSD, but has access to the whole data in the network (under the provision of granted access rights by the owner of the data). If the product is of interest, it can be requested from the local CSD. Request forwarding for not locally stored data and delivery is handled by the interconnected and synchronized CSDs. The CSD concept passed its first full-blown test during a major NATO exercise in Norway, Bold Avenger/Trial Quest 2007, which included real-time maneuvers by several thousand air and ground forces. In 2008 the concept was successfully tested during the Bundeswehr experiment Common Shield 2008. An adaptation of the concept has been tested in the project SOBCAH (Surveillance of borders, coastlines and harbours), partially funded by the European Commission under the Preparatory Action for Security Research (PASR) 2005 program. The proven benefit of information sharing through the CSD at the NATO exercise Bold Avenger/Trial Quest 2007 and the Bundeswehr experiment Common Shield 2008, led to the planning of fielding the CSD in NATO and Bundeswehr in 2009 - 2010.

13.6.8 Knowledge Mapping in Emergency Operations

R Lecocq.

This paper presents the preliminary results of an ongoing research on knowledge-mapping (k-mapping) conducted at Defence R&D Canada – Valcartier. A newly developed k-mapping prototype application called "KMapper", along with its underlying concepts and multidimensional approach are proposed. Knowledge mapping, as envisioned in this research, is aimed to enable the discovery, identification, localization, access and exploitation of key pieces of knowledge. The paper explains the knowledge mapping concepts and approach but also the specificities of the alpha prototype being developed as for instance how ontologies are key elements of the application. Subsequently, we discuss the promises of such an approach and application in response to some of the challenges faced by the NATO during crisis and emergency operations. Based on the demonstration results within a national/public security and Joint, Interagency, Multinational and Public (JIMP) contexts, it is realistic to infer some of the k-mapping added values to similar characteristics of coalition operations such as multiple parties' involvement, requirements for shared situation awareness as well as information/knowledge exchange. Finally, conclusions are drawn and some future work and researches are proposed.

13.6.9 The Oasis Approach to Civil / Military Information Sharing for Disaster and Emergency Management

A Cullen, S Barker, S Case, T Rye, B Rossow och E Wilkinson.

An accurate operating picture is essential for effective command and control during crises. This paper presents a framework for information sharing, developed within the EU FP6 Oasis project, that supports the construction of a common operating picture. This paper then describes how this framework was used to demonstrate civil/military information sharing between the UK fire, police and ambulance services, and the military in a fictitious aircraft crash scenario. Security for information sharing was provided by a data guard controlling transfers between different domains. The demonstration indicated the value of information sharing by improved handling of the emergency. The presentation of this broad area is an

overview but key issues are raised including information filtering and the role of users in development.

13.7 Artiklar från NATO RTO IST-RSY-087 on Information Management – Exploitation, Försvarshögskolan, Stockholm, Oktober 2009

Symposium arrangerat av NATO Research and Technology Organization, Information Systems Technology panel. Ordnat alfabetiskt efter titel.

13.7.1 Acquisition and Exploitation of Knowledge for Defence and Security

A Auger.

Defence and security analysts need to cope with huge amounts of information. They need to extract observational facts from a continuous flow of information and try to reason over it in order to better understand how facts are linked or networked together in given situations. Next generation of information system will be required to have extensive semantic capabilities and to be able to perform inference to derived new facts from factual observations. The first part of this paper presents a recent research activity conducted at Defence R&D Canada addressing some issues related to rapid semantic knowledge acquisition for information systems. The second part of this paper illustrates how new semantic and reasoning capabilities have been implemented in a Multi-Intelligence Tool Suite prototype.

13.7.2 Combining Different NLP Methods for HUMINT Report Analysis

C Jenge, S Kawaletz och U Schade.

In this paper we present a combined approach to the automatic (pre-) analysis of intelligence reports. The combination encompasses information extraction (IE) and information enrichment by means of ontologies. The combined approach proves to yield superior results compared to standalone IE. For our work we mainly use open standards and open source software. For the purpose of IE, for instance, we use the GATE system, whereas our ontology work is based on the W3C OWL standard and the Protégé ontology editor.

13.7.3 Detecting anomalies in open source information diffusion

F Nel, A Carré, P Capet och T Delavallade.

The adoption of the Internet as a massive information diffusion medium has considerably modified   information dynamics. An increasing amount of available information from uncontrolled, various and unreferenced sources makes this new mediatic environment suitable for various information diffusion phenomena like amplification phenomena that may affect significantly political, strategical or economical matters. Strategical or economical intelligence

analysts using open sources have to adapt their methods to face significant and changing information flows. In this context, they need automatic tools to select interesting phenomena among large quantities of data. This paper focuses on substantial variations in open source information diffusion that we call anomalies. Firstly, we introduce a model of a website network considering relevant parameters taking part in the dynamics of information flows over the Web. Then we propose a methodology based on this network to detect anomalies.

13.8 Artiklar från Skövde Workshop on Information Fusion Topics (SWIFT), Oktober 2009

Högskolan i Skövde (HiS) har under ett antal år bedrivit forskning inom området och även anordnat ett par Workshops. Ordnat alfabetiskt efter titel.

13.8.1 Evolving Petri Net Situation Templates for Situation Recognition

A Dahlbom och L Niklasson.

Situation recognition is an important problem to address in order to enhance the capabilities of modern surveillance systems. Situation recognition is concerned with finding a priori defined situations that possibly are instantiated in the present flow of information. It can be a rather tricky task to manually define templates for situations that evolve over time, and to at the same time achieve good results with respect to recall and precision on a situation recognition task. In this paper we present some initial results concerning the task of applying genetic algorithms to evolve Petri net based situation templates of interesting situations. Our results show that it is possible to evolve Petri nets that are on par with manually defined templates. However, more research is needed in order to establish the actual effects it has on recall and precision.

13.8.2 Pattern Recognition Using Queries in Relational Tracking Data Bases

G Schüller, W Koch, J Biermann, A Behrend och R Manthey.

Tracking systems provide kinematical information of objects in a scenario. This kinematical information can be combined with additional data to build higher-level-fusion systems that allow the detection of behaviour and threat patterns and thus contribute to situation awareness. The patterns that characterize situations of interest may vary over time and depend on the specific questions to be investigated. Data base systems provide a flexible way of combining data, and standing queries allow ongoing, automatic evaluation. In this paper, we present a way of using data base systems as the central component in a higher-level fusion system. We propose a possible architecture of this system using commercial database management software. Finally, we discuss how patterns for the detection of anomalies in tracking scenarios can be expressed in relational algebra.

13.8.3 Towards the Implementation of an Ontology-Based Reasoning System for Visual Information Fusion

J Gómez-Romero, J García, M A Patricio och J M. Molina.

High-level information fusion requires the use of abstract knowledge representation formalisms, such as ontologies. In previous research works, we proposed an ontology-based framework for visual information fusion aimed at contextual recognition of activities and enhancement of basic tracking procedures. In this paper, we describe various aspects of the implementation of this framework, focusing on the development of the supporting rule base.

13.9 Artiklar från Ontologies for the Intelligence Community (OIC) 2008, 2009 och Semantic Technologies for Intelligence, Defense, and Security (STIDS) 2010

Symposier hållna vid University Fairfax, Virginia Campus, 3 - 4 December 2008, 21 - 22 Oktober 2009, 27 - 28 Oktober 2010. OIC bytte namn till STIDS och utvidgade fokus år 2010. Proceedings finns på http://stids.c4i.gmu.edu/ (gällde november 2010). Ordnat alfabetiskt för varje år.

13.9.1 Automatic Ontology Creation from Text for National Intelligence Priorities Framework (NIPF)

M Balakrishna och M Srikanth. OIC 2008.

Analysts are constantly overwhelmed with large amounts of unstructured data. This holds especially true for intelligence analysts with the task of extracting useful information from large data sources. To alleviate this problem, domainspecific and general-purpose ontologies/knowledge-bases have been proposed to help automate methods for organizing data and provide access to useful information. However, problems in ontology creation and maintenance have resulted in expensive procedures for expanding/maintaining the ontology library available to support the growing and evolving needs of the Intelligence Community (IC). In this paper, we will present a semi-automatic development of an ontology library for the National Intelligence Priorities Framework (NIPF) topics. We use Jaguar-KAT, a state-of-the-art tool for knowledge acquisition and domain understanding, with minimized manual intervention to create NIPF ontologies loaded with rich semantic content. We also present evaluation results for the NIPF ontologies created using our methodology

13.9.2 Common Logic for an RDF Store

R MacGregor. OIC 2008.

The advent of commercial tools that support reasoning and management of RDF data stores provides a robust base for the growth of Semantic Web applications. There is as yet no analogous set of tools and products to support advanced logic-based applications. This article

examines issues that arise when seeking to combine the expressive power of Common Logic with the scalability of an RDF store.

13.9.3 Intelligence Analysis Ontology for Cognitive Assistants

M Boicu, G Tecuci och D Schum. OIC 2008.

This paper presents results on developing a general intelligence analysis ontology which is part of the knowledge base of Disciple-LTA, a unique and complex cognitive assistant for evidence-based hypothesis analysis that helps an intelligence analyst cope with many of the complexities of intelligence analysis. It introduces the cognitive assistant and overviews the various roles and the main components of the ontology: an ontology of "substance-blind" classes of items of evidence, an ontology of believability analysis credentials, and an ontology of actions involved in the chains of custody of the items of evidence.

13.9.4 Leveraging Emergent Ontologies in the Intelligence Community

J Starz, J Losco, B Kettler, R Hingst och C Rouff. OIC 2008.

The vision of a Semantic Web of intelligence knowledge has yet to be fully realized, in part because of the tough challenges of ontology engineering and maintenance. Recent developments on the World Wide Web and IC intranets demonstrate that individual users are willing to supply structured information conforming to de facto standards. This can be most prominently seen in "peer produced" folksonomies and knowledge bases such as Wikipedia and Intellipedia, its cousin. Though these structures lack the machine reasoning potential of highly engineered ontologies, for many purposes they are "good enough". This paper describes Contrail, a prototype information management application, that leverages an "emergent" ontology from Wikipedia to model a intelligence analyst's context and exploit that model to aid information retrieval, refinding, and sharing

13.9.5 Ontology of Evidence

K B Laskey, D A Schum, P C G Costa och T Janssen. OIC 2008.

Intelligence analysts rely on reports that are subject to many varieties of uncertainty, such as noise in sensors; deception or error by human sources; or cultural misunderstanding. To be effective, intelligence analysts must understand the relationship between reports, the events or situations reported upon, and the hypotheses of interest to which those events or situations are evidential. Computerized support for intelligence analysts must provide assistance for managing evidential reasoning. For this purpose, computational representations are needed for categories and relationships related to evidential reasoning, such as hypotheses, evidence, arguments, sources, and credibility. This paper describes some of the entities and relationships that belong in an ontology of evidence, and makes the case for the fundamental importance of a carefully engineered ontology of evidence to the enterprise of intelligence analysis.

13.9.6 Semantics for Information Sharing and Discovery in the Intelligence Community

M Thurn. OIC 2008.

One of the distinguishing characteristics of the intelligence community is the strict security framework that is used to control classified information. A counterproductive sideeffect of this strict security is that intelligence analysts are often not aware of information that is relevant to their analysis. Semantic technology and ontologies can help analysts discover relevant information even if that information is under the strictest controls and even if the analysts are not cleared to access the data. These techniques can be applied immediately within the current security framework of the intelligence community.

13.9.7 Unification of Geospatial Reasoning, Temporal Logic, & Social Network Analysis in an RDF Database

J Aasman. OIC 2008.

This paper is about a new type of event database that enables efficient reasoning about things, people, companies, relationships between people and companies, and about places and events. The event database is built on top of a scalable distributed RDF triple store that can handle literally billions of events. Like objects, events have at least one actor, but usually more, a start-time and possibly an end-time, a place where the event happened, and the type of the event. An event can have many additional properties and annotations. On top of this event database we implemented libraries for RDFS++ logic reasoning, for geospatial and temporal capabilities, and an extensive social network analysis package. This paper focuses on a query framework that makes it easy to combine all of the aforementioned capabilities in a user friendly query language.

13.9.8 An ontological approach to information access control and provenance

B Andersen. OIC 2009.

Recently, the US Intelligence Community (IC) has elevated the need to share information from a slogan to a policy in the form of Intelligence Community Directive (ICD) 501.1 The content of this directive can be summed up in one phrase: responsibility to share. However, the presence since the early 70s of well-established techniques and theory for multi-level security and access control have not solved the sharing problem; if they had, we would have been surprised by the advent of ICD 501. Of course access control is necessary – data stewards in member agencies will not share if, by doing so, they incur a risk of unauthorized release of information, especially when that information is related to specific sources and methods. Likewise, data consumers will not be incentivized to demand data held by stewards if that data cannot be trusted to be accurate, is of unknown origin, or lacks context. In other words, without providers, there is nothing to be shared and without consumers there is no reason to share. Thus, any viable policy for information sharing must rest on two interdependent notions: access control and provenance.

One could object that information sharing happens successfully all the time, e.g. on the internet via search engines. The conduct of science provides an example, where theories and experimental results are freely exchanged in an open, peer-reviewed environment. The key

term here, however, is open. Information sharing in the intelligence context shares few of the features of information sharing in science, save the universal desire to produce and use information. The community with interest in sharing intelligence information is, unlike science, closed and the information itself is, like science, epistemically unstable. It is these features of information sharing in the intelligence setting that underscore the need for both access control and provenance.

In an attempt to reconcile these two problems in a unified way, we take a step back and examine them through an ontological lens. That is, rather that starting from an abstract mathematical framework (e.g. [1]) we begin our investigation anew by asking what kinds of objects are involved and what are their properties.

13.9.9 Higher Order Uncertainty and Evidential Ontologies

J Brody. OIC 2009.

The uncertainties implicit in intelligence gathering are not only about the state of the world, but also about the ways in which varying contexts should affect the degree to which a proposition is believed. We call this latter form of uncertainty higher order uncertainty, and argue that the introduction of a logical operator to K. Laskey's MEBN specification can allow for learning about such uncertainty to occur.

13.9.10 Substance-Blind Classification of Evidence for Intelligence Analysis

D Schum, G Tecuci, M Boicu och Dorin Marcu. OIC 2009.

Intelligence analysis requires the development of arguments that link evidence to hypotheses by establishing and fusing the relevance, believability and inferential force or weight of a wide variety of items of evidence of different types. This paper presents several substance-blind classifications of evidence which are based on these inferential characteristics and facilitate the clarification of many uncertainties lur king in intelligence analysis. It also shows how the Disciple-L T A cognitive assistant uses these classifications to develop Wigmorean probabilistic inference networ ks for assessing the likelihood of hypotheses.

13.9.11 A Semantic Wiki Alerting Environment Incorporating Credibility and Reliability Evaluation

B Ulicny, C J. Matheus, och M M. Kokar. STIDS 2010.

In this paper, we describe a system that semantically annotates streams of reports about transnational criminal gangs in order to automatically produce models of the gangs' membership and activities in the form of a semantic wiki. A gang ontology and semantic inferencing are used to annotate the reports and supplement entity and relationship annotations based on the local document context. Reports in the datastream are annotated for reliability and credibility in the proof-of-concept system.

13.9.12 Maintaining Temporal Perspective

I Emmons och D Reid. STIDS 2010.

We present methods for annotating data with the time when it was learned and for answering queries according to what was known at any point in time. Specifically, we present an RDF knowledge representation that associates facts with their transaction times, and a query mechanism that transforms a time-agnostic SPARQL query and a point in time into a new, time-sensitive query. The transformed query yields the subset of the results of the original query that were valid at the indicated time. In addition, the methods presented here enable non-destructive merging of coreferences. These techniques apply broadly to storage and retrieval systems that require time-based versioning of data and are essential for maintaining temporal perspective in rapidly-evolving analytical environments.

13.9.13 Reified Literals: A Best Practice Candidate Design Pattern for Increased Expressivity in the Intelligence Community

E Peterson. STIDS 2010.

Reifying literals clearly increases expressivity. But reified literals appear to waste memory, slow queries, and complicate graph-based models. We show where this practice can be comparable to unreified literals in these respects and we characterize the cost where it is not. We offer examples of how reification allows literals to participate in a variety of relations enabling a marked increase in expressivity. We begin with a case study in reified person names, and then extend this analysis to reified dates and simple reified scalar values. We show benefits for name matching and temporal analysis such as would be of interest to the Intelligence Community (IC). We then show how these same sorts of analyses can drive or inform any decision as to whether to reify literals.

13.9.14 Semantic Wiki for Visualization of Social Media Analysis

D Reininger, D Ihrie, och B Bullard. STIDS 2010.

A semantic wiki provides visualization of social media analysis applicable to military Information Operations and law enforcement counterterrorism efforts. Using inputs from disparate data sets, semantic software exports data to link analysis, geospatial displays, and temporal representation. Challenges encountered in software development include the balance between automated and human assisted entity extraction, interoperability with existing visualization systems and ontology management.

13.9.15 TIACRITIS System and Textbook: Learning Intelligence Analysis through Practice

G Tecuci, M Boicu, D Marcu, D Schum, och B Hamilton. STIDS 2010.

This paper presents the TIACRITIS web agent and textbook for teaching intelligence analysts the critical thinking skills needed to perform evidence-based reasoning. They are based on a computational theory which views Intelligence Analysis as ceaseless discovery of evidence, hypotheses, and arguments, in a complex world that is changing all the time. TIACRITIS helps students learn about the properties, uses, and marshaling of evidence upon which all analyses rest, through regular practice involving analyses of evidence in both hypothetical and real situations.

13.10 Artiklar från ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD) 2009, 2010.

Ordnat alfabetiskt efter titel. Hyperlänk till artikel bifogas (aktuell slutet av November 2010).

13.10.1 Cross Domain Distribution Adaptation via Kernel Mapping

E Zhong, W Fan, J Peng, K Zhang, J Ren, D Turaga och O Verscheure. KDD 2009.

When labeled examples are limited and difficult to obtain, transfer learning employs knowledge from a source domain to improve learning accuracy in the target domain. However, the assumption made by existing approaches, that the marginal and conditional probabilities are directly related between source and target domains, has limited applicability in either the original space or its linear transformations. To solve this problem, we propose an adaptive kernel approach that maps the marginal distribution of targetdomain and source-domain data into a common kernel space, and utilize a sample selection strategy to draw conditional probabilities between the two domains closer. We formally show that under the kernel-mapping space, the difference in distributions between the two domains is bounded; and the prediction error of the proposed approach can also be bounded. Experimental results demonstrate that the proposed method outperforms both traditional inductive classifiers and the state-of-the-art boosting-based transfer algorithms on most domains, including text categorization and web page ratings. In particular, it can achieve around 10% higher accuracy than other approaches for the text categorization problem. The source code and datasets are available from the authors.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p1027.pdf

13.10.2 Exploiting Wikipedia as External Knowledge for Document Clustering

X Hu, X Zhang, C Lu, E. K. Park och X Zhou. KDD 2009.

In traditional text clustering methods, documents are represented as "bags of words" without considering the semantic information of each document. For instance, if two documents use different collections of core words to represent the same topic, they may be falsely assigned to different clusters due to the lack of shared core words, although the core words they use are probably synonyms or semantically associated in other forms. The most common way to solve this problem is to enrich document representation with the background knowledge in an ontology. There are two major issues for this approach: (1) the coverage of the ontology is limited, even for WordNet or Mesh, (2) using ontology terms as replacement or additional features may cause information loss, or introduce noise. In this paper, we present a novel text clustering method to address these two issues by enriching document representation with Wikipedia concept and category information. We develop two approaches, exact match and relatedness-match, to map text documents to Wikipedia concepts, and further to Wikipedia categories. Then the text documents are clustered based on a similarity metric which combines document content information, concept information as well as category information. The

experimental results using the proposed clustering framework on three datasets (20-newsgroup, TDT2, and LA Times) show that clustering performance improves significantly by enriching document representation with Wikipedia concepts and categories.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p389.pdf

13.10.3 Finding a Team of Experts in Social Networks

T Lappas, K Liu och E Terzi. KDD 2009.

Given a task T, a pool of individuals X with different skills, and a social network G that captures the compatibility among these individuals, we study the problem of finding X0, a sub-set of X, to perform the task. We call this the Team Formation problem. We require that members of X0 not only meet the skill requirements of the task, but can also work effectively together as a team. We measure effectiveness using the communication cost incurred by the subgraph in G that only involves X0. We study two variants of the problem for two different communication-cost functions, and show that both variants are NP-hard. We explore their connections with existing combinatorial problems and give novel algorithms for their solution. To the best of our knowledge, this is the first work to consider the Team Formation problem in the presence of a social network of individuals. Experiments on the DBLP dataset show that our framework works well in practice and gives useful and intuitive results.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p467.pdf

13.10.4 Frequent Pattern Mining with Uncertain Data

C C Aggarwal, Y Li, J Wang och J Wang. KDD 2009.

This paper studies the problem of frequent pattern mining with uncertain data. We will show how broad classes of algorithms can be extended to the uncertain data setting. In particular, we will study candidate generate-and-test algorithms, hyper-structure algorithms and pattern growth based algorithms. One of our insightful observations is that the experimental behavior of different classes of algorithms is very different in the uncertain case as compared to the deterministic case. In particular, the hyper-structure and the candidate generate-and-test algorithms perform much better than tree-based algorithms. This counter-intuitive behavior is an important observation from the perspective of algorithm design of the uncertain variation of the problem. We will test the approach on a number of real and synthetic data sets, and show the effectiveness of two of our approaches over competitive techniques. Executable and Data Sets: Available at:

http://dbgroup.cs.tsinghua.edu.cn/liyan/u mining.tar.gz

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p29.pdf

13.10.5 Large Human Communication Networks: Patterns and a Utility-Driven Generator

N Du, C Faloutsos, B Wang och L Akoglu. KDD 2009.

Given a real, and weighted person-to-person network which changes over time, what can we say about the cliques that it contains? Do the incidents of communication, or weights on the edges of a clique follow any pattern? Real, and in-person social networks have many more

triangles than chance would dictate. As it turns out, there are many more cliques than one would expect, in surprising patterns. In this paper, we study massive real-world social networks formed by direct contacts among people through various personal communication services, such as Phone-Call, SMS, IM etc. The contributions are the following: (a) we discover surprising patterns with the cliques, (b) we report power-laws of the weights on the edges of cliques, (c) our real networks follow these patterns such that we can trust them to spot outliers and finally, (d) we propose the first utility-driven graph generator for weighted time-evolving networks, which match the observed patterns. Our study focused on three large datasets, each of which is a different type of communication service, with over one million records, and spans several months of activity.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p269.pdf

13.10.6 Ranking-Based Clustering of Heterogeneous Information Networks with Star Network Schema

Y Sun, Y Yu och Jiawei Han. KDD 2009.

A heterogeneous information network is an information network composed of multiple types of objects. Clustering on such a network may lead to better understanding of both hidden structures of the network and the individual role played by every object in each cluster. However, although clustering on homogeneous networks has been studied over decades, clustering on heterogeneous networks has not been addressed until recently. A recent study proposed a new algorithm, RankClus, for clustering on bi-typed heterogeneous networks. However, a real-world network may consist of more than two types, and the interactions among multi-typed objects play a key role at disclosing the rich semantics that a network carries. In this paper, we study clustering of multi-typed heterogeneous networks with a star network schema and propose a novel algorithm, NetClus, that utilizes links across multityped objects to generate high-quality net-clusters. An iterative enhancement method is developed that leads to effective ranking-based clustering in such heterogeneous networks. Our experiments on DBLP data show that NetClus generates more accurate clustering results than the baseline topic model algorithm PLSA and the recently proposed algorithm, RankClus. Further, NetClus generates informative clusters, presenting good ranking and cluster membership information for each attribute object in each net-cluster.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p797.pdf

13.10.7 WhereNext: a Location Predictor on Trajectory Pattern Mining

A Monreale, F Pinelli, R Trasarti och F Giannotti. KDD 2009.

The pervasiveness of mobile devices and location based services is leading to an increasing volume of mobility data. This side effect provides the opportunity for innovative methods that analyse the behaviors of movements. In this paper we propose WhereNext, which is a method aimed at predicting with a certain level of accuracy the next location of a moving object. The prediction uses previously extracted movement patterns named Trajectory Patterns, which are a concise representation of behaviors of moving objects as sequences of regions frequently visited with a typical travel time. A decision tree, named T-pattern Tree, is built and evaluated with a formal training and test process. The tree is learned from the Trajectory Patterns that hold a certain area and it may be used as a predictor of the next location of a new trajectory

finding the best matching path in the tree. Three different best matching methods to classify a new moving object are proposed and their impact on the quality of prediction is studied extensively. Using Trajectory Patterns as predictive rules has the following implications: (I) the learning depends on the movement of all available objects in a certain area instead of on the individual history of an object; (II) the prediction tree intrinsically contains the spatio-temporal properties that have emerged from the data and this allows us to define matching methods that striclty depend on the properties of such movements. In addition, we propose a set of other measures, that evaluate a priori the predictive power of a set of Trajectory Patterns. This measures were tuned on a real life case study. Finally, an exhaustive set of experiments and results on the real dataset are presented.

http://www-ai.cs.uni-dortmund.de/PROCEEDINGS/SIKDD2009/docs/p637.pdf

13.10.8 Connecting the Dots Between News Articles

D Shahaf och C Guestrin. KDD 2010.

The process of extracting useful knowledge from large datasets has become one of the most pressing problems in today's society. The problem spans entire sectors, from scientists to intelligence analysts and web users, all of whom are constantly struggling to keep up with the larger and larger amounts of content published every day. With this much data, it is often easy to miss the big picture. In this paper, we investigate methods for automatically connecting the dots – providing a structured, easy way to navigate within a new topic and discover hidden connections. We focus on the news domain: given two news articles, our system automatically finds a coherent chain linking them together. For example, it can recover the chain of events starting with the decline of home prices (January 2007), and ending with the ongoing health-care debate. We formalize the characteristics of a good chain and provide an efficient algorithm (with theoretical guarantees) to connect two fixed endpoints. We incorporate user feedback into our framework, allowing the stories to be refined and personalized. Finally, we evaluate our algorithm over real news data. Our user studies demonstrate the algorithm's effectiveness in helping users understanding the news.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p623.pdf

13.10.9 Discovery of Significant Emerging Trends

S Goorha och L Ungar. KDD 2010.

We describe a system that monitors social and mainstream media to determine shifts in what people are thinking about a product or company. We process over 100,000 news articles, blog posts, review sites, and tweets a day for mentions of items (e.g., products) of interest, extract phrases that are mentioned near them, and determine which of the phrases are of greatest possible interest to, for example, brand managers. Case studies show a good ability to rapidly pinpoint emerging subjects buried deep in large volumes of data and then highlight those that are rising or falling in significance as they relate to the firms interests. The tool and algorithm improves the signal-to-noise ratio and pinpoints precisely the opportunities and risks that matter most to communications professionals and their organizations.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p57.pdf

13.10.10   Inferring Networks of Diffusion and Influence

M Gomez-Rodriguez, J Leskovec och A Krause. KDD 2010.

Information diffusion and virus propagation are fundamental processes talking place in networks. While it is often possible to directly observe when nodes become infected, observing individual transmissions (i.e., who infects whom or who influences whom) is typically very difficult. Furthermore, in many applications, the underlying network over which the diffusions and propagations spread is actually unobserved. We tackle these challenges by developing a method for tracing paths of diffusion and influence through networks and inferring the networks over which contagions propagate. Given the times when nodes adopt pieces of information or become infected, we identify the optimal network that best explains the observed infection times. Since the optimization problem is NP-hard to solve exactly, we develop an efficient approximation algorithm that scales to large datasets and in practice gives provably near-optimal performance. We demonstrate the effectiveness of our approach by tracing information cascades in a set of 170 million blogs and news articles over a one year period to infer how information flows through the online media space. We find that the diffusion network of news tends to have a core-periphery structure with a small set of core media sites that diffuse information to the rest of the Web. These sites tend to have stable circles of influence with more general news media sites acting as connectors between them.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p1019.pdf

13.10.11   MalStone: Towards A Benchmark for Analytics on Large Data Clouds

C Bennett, Rt L Grossman, D Locke, J Seidman och S Vejcik. KDD 2010.

Developing data mining algorithms that are suitable for cloud computing platforms is currently an active area of research, as is developing cloud computing platforms appropriate for data mining. Currently, the most common benchmark for cloud computing is the Terasort (and related) benchmarks. Although the Terasort Benchmark is quite useful, it was not designed for data mining per se. In this paper, we introduce a benchmark called MalStone that is specically designed to measure the performance of cloud computing middleware that supports the type of data intensive computing common when building data mining models. We also introduce MalGen, which is a utility for generating data on clouds that can be used with MalStone.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p145.pdf

13.10.12   MineFleet®: An Overview of a Widely Adopted Distributed Vehicle Performance Data Mining System

H Kargupta, K Sarkar och M Gilligan. KDD 2010.

This paper describes the MineFleet® distributed vehicle performance data mining system designed for commercial fleets. MineFleet analyzes high throughput data streams onboard the vehicle, generates the analytics, sends those to the remote server over the wide-area wireless networks and offers them to the fleet managers using stand-alone and web-based user-interface. The paper describes the overall architecture of the system, business needs, and shares experience from successful large-scale commercial deployments. MineFleet is probably one of the first commercially successful distributed data stream mining systems. This patented technology has been adopted, productized, and commercially offered by many large

companies in the mobile resource management and GPS fleet tracking industry. This paper offers an overview of the system and offers a detailed analysis of what made it work.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p37.pdf

13.10.13 Semantic Relation Extraction With Kernels Over Typed Dependency Trees

F Reichartz H Korte och Gerhard Paass. KDD 2010.

An important step for understanding the semantic content of text is the extraction of semantic relations between entities in natural language documents. Automatic extraction techniques have to be able to identify different versions of the same relation which usually may be expressed in a great variety of ways. Therefore these techniques benefit from taking into account many syntactic and semantic features, especially parse trees generated by automatic sentence parsers. Typed dependency parse trees are edge and node labeled parse trees whose labels and topology contains valuable semantic clues. This information can be exploited for relation extraction by the use of kernels over structured data for classification. In this paper we present new tree kernels for relation extraction over typed dependency parse trees. On a public benchmark data set we are able to demonstrate a significant improvement in terms of relation extraction quality of our new kernels over other state-of-the-art kernels.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p773.pdf

13.10.14 TIARA: A Visual Exploratory Text Analytic System

F Wei, S Liu, Y Song, S Pan, M X Zhou, W Qian, L Shi, L Tan och Q Zhang. KDD 2010.

In this paper, we present a novel exploratory visual analytic system called TIARA (Text Insight via Automated Responsive Analytics), which combines text analytics and interactive visualization to help users explore and analyze large collections of text. Given a collection of documents, TIARA first uses topic analysis techniques to summarize the documents into a set of topics, each of which is represented by a set of keywords. In addition to extracting topics, TIARA derives time-sensitive keywords to depict the content evolution of each topic over time. To help users understand the topic-based summarization results, TIARA employs several interactive text visualization techniques to explain the summarization results and seamlessly link such results to the original text. We have applied TIARA to several real-world applications, including email summarization and patient record analysis. To measure the effectiveness of TIARA, we have conducted several experiments. Our experimental results and initial user feedback suggest that TIARA is effective in aiding users in their exploratory text analytic tasks.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p153.pdf

13.10.15 The Topic-Perspective Model for Social Tagging Systems

C Lu, X Hu, X Chen, J-R Park, T T He och Z Li. KDD 2010.

In this paper, we propose a new probabilistic generative model, called Topic-Perspective Model, for simulating the generation process of social annotations. Different from other

generative models, in our model, the tag generation process is separated from the content term generation process. While content terms are only generated from resource topics, social tags are generated by resource topics and user perspectives together. The proposed probabilistic model can produce more useful information than any other models proposed before. The parameters learned from this model include: (1) the topical distribution of each document, (2) the perspective distribution of each user, (3) the word distribution of each topic, (4) the tag distribution of each topic, (5) the tag distribution of each user perspective, (6) and the probabilistic of each tag being generated from resource topics or user perspectives. Experimental results show that the proposed model has better generalization performance or tag prediction ability than other two models proposed in previous research.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p683.pdf

13.10.16 Why Label when you can Search? Alternatives to Active Learning for Applying Human Resources to Build Classification Models Under Extreme Class Imbalance

J Attenberg och F Provost. KDD 2010.

This paper analyses alternative techniques for deploying low-cost human resources for data acquisition for classifier induction in domains exhibiting extreme class imbalance where traditional labeling strategies, such as active learning, can be ineffective. Consider the problem of building classifiers to help brands control the content adjacent to their on-line advertisements. Although frequent enough to worry advertisers, objectionable categories are rare in the distribution of impressions encountered by most on-line advertisers|so rare that traditional sampling techniques do not find enough positive examples to train effective models. An alternative way to deploy human resources for training-data acquisition is to have them "guide" the learning by searching explicitly for training examples of each class. We show that under extreme skew, even basic techniques for guided learning completely dominate smart (active) strategies for applying human resources to select cases for labeling. Therefore, it is critical to consider the relative cost of search versus labeling, and we demonstrate the tradeoffs for different relative costs. We show that in cost/skew settings where the choice between search and active labeling is equivocal, a hybrid strategy can combine the benefits.

http://users.cs.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p423.pdf

14 Övriga Tidskrifter och Rapporter samt övriga Konferenser, Symposia och Workshops

14.1 Övriga Tidskrifter och Rapporter

Ordnade alfabetiskt efter titel.

14.1.1 BeAware!—Situation awareness, the ontology-driven way

N Baumgartner, W Gottesheim, S Mitsch, W Retschitzegger och W Schwinger. Data & Knowledge Engineering, Vol. 69, Nr. 11, November 2010, s. 1181-1193.

Information overload is a severe problem for human operators of large-scale control systems as, for example, encountered in the domain of road traffic management. Operators of such systems are at risk to lack situation awareness, because existing systems focus on the mere presentation of the available information on graphical user interfaces—thus endangering the timely and correct identification, resolution, and prevention of critical situations. In recent years, ontology-based approaches to situation awareness featuring a semantically richer knowledge model have emerged. However, current approaches are either highly domain-specific or have, in case they are domain-independent, shortcomings regarding their reusability.

In this paper, we present our experience gained from the development of BeAware!, a framework for ontology-driven information systems aiming at increasing an operator's situation awareness. In contrast to existing domain-independent approaches, BeAware!'s ontology introduces the concept of spatio-temporal primitive relations between observed real-world objects thereby improving the reusability of the framework. To show its applicability, a prototype of BeAware! has been implemented in the domain of road traffic management. An overview of this prototype and lessons learned for the development of ontology-driven information systems complete our contribution.

14.1.2 Discovering and Explaining Abnormal Nodes in Semantic Graphs

Shou-de Lin and Hans Chalupsky. IEEE Transactions on Knowledge and Data Engineering, Vol. 20, Nr. 8, Augusti 2008.

An important problem in the area of homeland security is to identify abnormal or suspicious entities in large data sets. Although there are methods from data mining and social network analysis focusing on finding patterns or central nodes from networks or numerical data sets, there has been little work aimed at discovering abnormal instances in large complex semantic graphs, whose nodes are richly connected with many different types of links. In this paper, we describe a novel unsupervised framework to identify such instances. Besides discovering abnormal instances, we believe that to complete the process, a system has to also provide users with understandable explanations for its findings. Therefore, in the second part of the paper,

we describe an explanation mechanism to automatically generate human-understandable explanations for the discovered results. To evaluate our discovery and explanation systems, we perform experiments on several different semantic graphs. The results show that our discovery system outperforms stateof-the-art unsupervised network algorithms used to analyze the 9/11 terrorist network and other graph-based outlier detection algorithms by a significant margin. Additionally, the human study we conducted demonstrates that our explanation system, which provides natural language explanations for the system's findings, allowed human subjects to perform complex data analysis in a much more efficient and accurate manner.

14.1.3 Envisioning uncertainty in geospatial information

K B Laskey, E J Wright och P C G da Costa. International Journal of Approximate Reasoning, Vol. 51, Nr. 2, Januari 2010, s. 209-223.

Geospatial reasoning has been an essential aspect of military planning since the invention of cartography. Although maps have always been a focal point for developing situational awareness, the dawning era of network-centric operations brings the promise of unprecedented battlefield advantage due to improved geospatial situational awareness. Geographic information systems (GIS) and GIS-based decision support systems are ubiquitous within current military forces, as well as civil and humanitarian organizations. Understanding the quality of geospatial data is essential to using it intelligently. A systematic approach to data quality requires: estimating and describing the quality of data as they are collected; recording the data quality as metadata; propagating uncertainty through models for data processing; exploiting uncertainty appropriately in decision support tools; and communicating to the user the uncertainty in the final product. There are shortcomings in the state-of-the-practice in GIS applications in dealing with uncertainty. No single point solution can fully address the problem. Rather, a system-wide approach is necessary. Bayesian reasoning provides a principled and coherent framework for representing knowledge about data quality, drawing inferences from data of varying quality, and assessing the impact of data quality on modeled effects. Use of a Bayesian approach also drives a requirement for appropriate probabilistic information in geospatial data quality metadata. This paper describes our research on data quality for military applications of geospatial reasoning, and describes model views appropriate for model builders, analysts, and end users.

14.1.4 Issues with Developing Situation and Threat Assessment Capabilities

J Couture och E Menard. Harbour Protection Through Data Fusion Technologies. NATO Science for Peace and Security Series C: Environmental Security, 2009, p. 171-179.

Lockheed Martin Canada has recently developed a Situation and Threat Assessment (STA) and Resource Management (RM) application using some recent technologies and concepts that have emerged from level 2 and 3 data fusion research. The current paper focuses on the issues pertaining to the design and implementation of threat opportunity, capability, and intent in threat assessment computation. The discussion about intent is particularly relevant for harbour protection since it is the key factor in identifying asymmetric threats.

14.1.5 Mixed-Initiative Assumption-Based Reasoningfor Complex Decision-Making

This paper discusses several critical capabilities of the Disciple-LTA system for complex problem-solving and decision-making, including a transparent and easy to understand reasoning process, a flexible and natural collaboration with the user, and the use of what-if scenarios to cope with incomplete and uncertain information. They allow the user to act as the orchestrator of the reasoning process, guiding the high-level exploration of the decision-making space, while the system implements this guidance by taking into account the user's preferred problem solving strategies, assumptions and biases. These capabilities are discussed in the context of intelligence analysis.

14.1.6 Sensor Resource Management driven by threat projection and priorities

This paper extends previous Sensor Resource Management (SRM) work by addressing information flow from sensor inputs to SRM, through four levels of the US DoD's Joint Directors of Laboratories (JDL) sensorfusion model. The method flexibly adapts to several domains/problems. Human situation awareness information needs are linked to sensor control in a manner similar to perception management. The key to effective integrationof JDL levels is the timely determination of the highest priorities via threat projection accomplished via Probabilistic Accumulative Situation Calculus (PASC), which quantifies threat intent using an appropriate level of automated context-based reasoning. The accuracy of the threat projection is improved over time using selflearning techniques. The multiple sensor system levels are unified primarily using the structure of quantified priorities. Algorithms are presented for a radar sensor resource allocation and adjustment method in which the dwell time per track parameter is the key radar sensor resource to be managed. A developed application of the method to an Integrated Air Defense System (IADS) sensor system problem is detailed, with simulation results shown to demonstrate the effectiveness of the method.

14.1.7 Situational Behavior Modeling

Behavior modeling for military applications needs to consider systems in which all kind of entities participate – machines, humans, human organizations (like platoons or companies) as well as such complex entities like countries, industries and societies. The variety and the structure of entities participating in behaviors in the military domain require the use of representations and tools appropriate for this kind of complexity. Ontological modeling seems to be the best match for this domain. However, there are no known results in the literature on modeling and tracking of behaviors using an ontological approach in which automatic inference over the dynamic models of behaviors can be carried out using inference tools. A behavior model can be conceptualized in a number of ways - as an abstract concept that is independent of any physical or conceptual entity, as a feature of a specific entity, or as an

abstract concept that is associated with one or more physical or conceptual entities. Various knowledge representation mechanisms including State Machines, Hidden Markov Models, Petri Nets, Game Theoretic Models and Bayesian Networks have been used extensively for behavior modeling. Most of the studies have been focusing on modeling behavior of a specific type of entity. For instance, organizational behavior modeling considers an organization as a system of interrelated entities (humans) and then develops models for behavior of humans within an organization.

In the approach presented in this document, behavior is treated as being associated with a situation, i.e., with a number of objects (e.g., an organization) being in some relations with each other. While situation objects will normally have some basic behaviors associated by default, they will be able to participate in complex behaviors involving multiple situation objects. Those complex behaviors can occur in a situation, and not just as inherent features of a specific object. Thus behaviors are treated as situation objects. In this project we have developed an ontology for situations and then extended it to represent abstract behaviors of situational objects.

The new approach to behavior modeling requires the development of models, techniques and tools that can support both the analyst and the developer in the process of employing this new concept in operational scenarios. With such tools, not only will the analyst be able to employ a system for monitoring whether a specific situation has occurred, but also to track situations. While the term 'tracking situations' has been used in the information fusion community, it has been used primarily in the sense of generating indicators and warnings when the situation occurs. In the concept presented in this report, behavioural situations are considered as dynamic entities having states, with transitions from one state to another resulting from actions executed by entities participating in a specific behaviour that are either inside or outside of the situation being tracked. In this project we have conceptualized various tools, including tools for situational behavior modeling, tracking and learning.

14.2 Övriga Konferenser, Symposia och Workshops

Ordnade alfabetiskt efter titel.

14.2.1 Agent-based Cognitive approach to Airport Security Situation Awareness

G Fenza, D Furno, V Loia och M Veniero. Proc. Int. Conf. on Complex, Intelligent and Software Intensive Systems (CISIS), 2010.

Situation awareness is crucial factor in decision-making. It involves monitoring and identification of relationships among objects in collaborative dynamic environments. In the domain of Airport Security one of the main needs is to support the security operator to manage in real-time risk scenarios in the airside. This work relies on a cognitive approach to model the awareness ontology and introduces an agent-based architecture to address the problem. In particular, in order to model situation awareness the work instantiates the generic Situation Theory Ontology(STO) in the specific domain of airport security. Furthermore, some task-oriented agents allow to distribute the information in order to achieve better performances.

14.2.2 Construction of Fuzzy Ontology-Based Terrorism Event Extraction

U Inyaem, P Meesad, C Haruechaiyasak, D Tran. Proc. Int. Conf. on Knowledge Discovery and Data Mining, 2010. WKDD '10, s. 391 – 394.

Fuzzy ontology is based on the concept that each index object is related to every other object in the ontology, with a degree of membership assigned to that relationship based on fuzzy set theory. This paper proposes use cases based on the related process of the terrorism event extraction using fuzzy ontology, especially the terrorism fuzzy ontology construction methodology. The related use cases are represented using the Web Ontology Language (OWL) which is designed to support the representation ontology relation. Additionally, to make the proposed use cases more relevant to implementing the system, the paper presents linguistic variables which serve as a mean of approximate characterization of fuzzy phenomena concepts and also the appropriate characterization of the terrorism fuzzy relations in their properties.

14.2.3 Introducing Semantic Knowledge in High-Level Fusion

C. Laudy och J.-G. Ganascia. Proc. IEEE conference on Military communications, MILCOM, 2009.

The necessity of taking into account high-level information has recently been reported by the information fusion community. We previously presented an approach for high-level symbolic fusion that relies on the use of the conceptual graphs model. Domain knowledge is a major point of the fusion process. The use of conceptual graphs for knowledge representation eases the process of expressing domain knowledge and fusion heuristics. We use conceptual graphs in order to model a situation of interest. Information items extracted from different sources are fused, using the model of situation in order to orient the fusion by delivering a context. This article details a step that was introduced prior to fusion, that aims at testing the compatibility of observations. It explains the way the domain knowledge is introduced inside the compatibility test, similarly as it was previously introduced in the fusion process. The proposed approach is illustrated within the context of a decision support system for geopolitical crisis management.

14.2.4 Network Threat Assessment Based on Attribute Recognition

J Si, Q Zhang, D Man, K Wang och W Yang. Int Conf. on Advanced Communication Technology, 2009.

Network threat assessment is an important branch of information security assessment. Its research involves data fusion and data mining. This paper provided an overview of related research efforts in the area of network threat assessment. It presented a network threat assessment framework, and demonstrated a computational approach based on attribute recognition theory. In the computational example, entropy value method is used to determine the index weight. The example's result indicates that attribute recognition theory is simple, practical and able to evaluate network threats effectively.

14.2.5 Ontology-Based Fuzzy Semantic Clustering

Y Cheng. Proc. Int Conf on Convergence and Hybrid Information Technology (ICCIT), 2008, s. 128 - 133.

Document clustering plays an important role in providing intuitive navigation and browsing mechanisms by organizing large amounts of documents into a small number of meaningful clusters. Most of the documents clustering methods were grounded in the bag of words representation to measure similarity, ignoring the semantic relationships between words that do not co-occur literally. A novel fuzzy semantic method that integrates ontology as background knowledge into the process of computing similarity between documents is proposed so as to improve the performance of documents clustering in terms of quality and efficiency. Ontology is represented as a graph-based model that reflects semantic relationship between concepts, with which a semantic similarity matrix of concepts that exploits semantic relation of the ontology is defined. Based on conceptual matrix a document can be represented to a semantic fuzzy set. Then similarity between documents is computed with fuzzy matching measure. The result of this process may make documents not similar with vector representation become similar. Maximal fuzzy spanning tree algorithm is used as a document-clustering algorithm. Finally the efficacy of our approach is demonstrated through relevant experiments.

14.2.6 Situation Tracking: The Concept and a Scenario

M M Kokar, J J Letkowski, R Dionne och C J Matheus. Proc. IEEE conference on Military communications, MILCOM, 2008.

Situation Awareness makes a step forward from the previous focus on Level 1 information processing and fusion, as defined by the JDL Model. However, in most approaches the meaning of 'situation awareness' is limited to knowing whether a particular relation holds or not. In our approach, situations are considered as entities that can affect, exhibit and participate in various behaviors. This requires a clear understanding of the meaning of a new concept – 'behavioral situation'. We use the term 'situational behavior' to refer to a collective response to an event generated by a collection of objects in a situation. This in turn leads to the notion of 'behavioral situation modeling' that refers to the activity of modeling situational behaviors. In this paper we show an ontology that can be used to capture abstract behaviors. This ontology is an extension of the ontology for situation awareness. Here behavioural situations are considered as dynamic entities having states, with transitions from one state to another resulting from events generated by entities participating in a specific behavior, and thus can be tracked. In this paper we discuss a scenario that will show examples of 'situational states' as well as 'events'. The whole scenario is embedded in the formalism of State Machines, where particular states are modeled as 'situation types'. All models are expressed in terms of an ontology for situational behaviors.

14.2.7 Using standards of the Open Geospatial Consortium to support data and information fusion

K Watson (OGC). Föredrag vid trilateral workshop SWE-GER-NLD I Euskirchen, Tyskland, maj 2010.

The Open Geospatial Consortium (OGC) has developed and continues to develop a suite of standards dealing with geo-information systems and sensor networks. In particular, the Sensor Web Enablement (SWE) standards family includes the Sensor Observation Service (to access

sensor data), the Sensor Planning Service (to configure and task sensors and other resources), the Sensor Alert Service and Web Notification Service. These services are complemented by the information models Observation & Measurement Model (a fundamental conceptual cornerstone) and the Sensor Model Language (to describe sensors). Furthermore, OGC has recently released a public report "OGC Fusion Standards Study Engineering Report" dealing with techniques and standards for data and information fusion (http://portal.opengeospatial.org/files/?artifact_id=36177&version=2). The report defines fusion as follows: "Fusion is the act or process of combining or associating data or information regarding one or more entities considered in an explicit or implicit knowledge framework to improve one's capability (or provide a new capability) for detection, identification, or characterization of that entity". The OGC engineering report covers recommendations for fusion standards in three categories: sensor fusion, object/feature fusion and decision fusion. It addresses point observations, images and object (or feature) related data. Moreover, the report includes example architectures for fusion, including distributed processing, web services, registries and IT standards. The OGC report was produced on the basis of contributions by ten different sources from diverse sectors, including the security and defence sector. Fraunhofer IOSB is an active OGC member and was one of these contributors. The presentation will give an overview of the OGC Fusion Standards Study Engineering Report and the usage of OGC standards for data and information fusion. Recent R&D work of Fraunhofer IOSB in the area of sensor service networks for environmental risk management will be used to illustrate the possible application of OGC standards.

15 Appendix 1: Sökord för genomförda sökningar i databaser

För den intresserade läsaren, och för att lista åtskilliga av de nyckelord som är relevanta för området: Sju sökningar i internationella publikationsdatabaser gjordes för att hitta potentiellt intressanta publikationer, med nedanstående logiska kombinationer av sökord:

1. fusion OCH (situation tracking ELLER threat assessment ELLER semantic network ELLER structured argumentation ELLER open source intelligence ELLER plan recognition ELLER information acquisition ELLER mixed initiative)

2. intelligence analysis OCH (ontology ELLER situation awareness ELLER indicator ELLER semantic network ELLER intent ELLER structured argumentation ELLER plan recognition ELLER information acquisition ELLER mixed initiative)

3. knowledge representation OCH (situation awareness ELLER situation assessment ELLER situation tracking ELLER threat assessment ELLER indicator ELLER semantic network ELLER intent ELLER structured argumentation ELLER open source intelligence ELLER plan recognition ELLER information acquisition ELLER mixed initiative ELLER high-level fusion)

4. automated reasoning OCH (situation awareness ELLER situation assessment ELLER situation tracking ELLER threat assessment ELLER indicator ELLER semantic network ELLER intent ELLER structured argumentation ELLER open source intelligence ELLER plan recognition ELLER information acquisition ELLER mixed initiative)

5. graph matching ELLER template matching

6. (probabilistic ELLER fuzzy ELLER uncertainty) OCH (ontology ELLER knowledge representation)

7. situation calculus