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1 (6)

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Accoustic and visual sensor network measurements in Lilla Gåra 2012

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1 Introduction

This document describes the measurement campaign performed with acoustic and visual sensors on the Lilla Gåra in May 8–9, 2012. The purpose of the campaign was to collect data to allow for target tracking of ground and aerial targets using both acoustics (Doppler shift as well as time of arrival type measurements) and image analysis; and to collect data to evaluate methods for calibration of acoustic sensor networks. The focus of the presentation lies on describing the sensors used as well as the experiments performed.

Lilla Gåra is a test site maintained by the Swedish Defence Research Agency (FOI) in the countryside south of the city Linköping, Sweden. The site contains a 200 by 100 meter field covered with gravel. The surroundings are such that reflections of sounds originating from the field can be assumed minimal. See Figure 1 for a satellite photo of the Lilla Gåra test site. The remote location furthermore provides for a low level of acoustic background noise.

This memo is organized the following way: first, in Section 2, the sensors used during the measurement campaign are described, before the experiments conducted are outlined in Section 3.

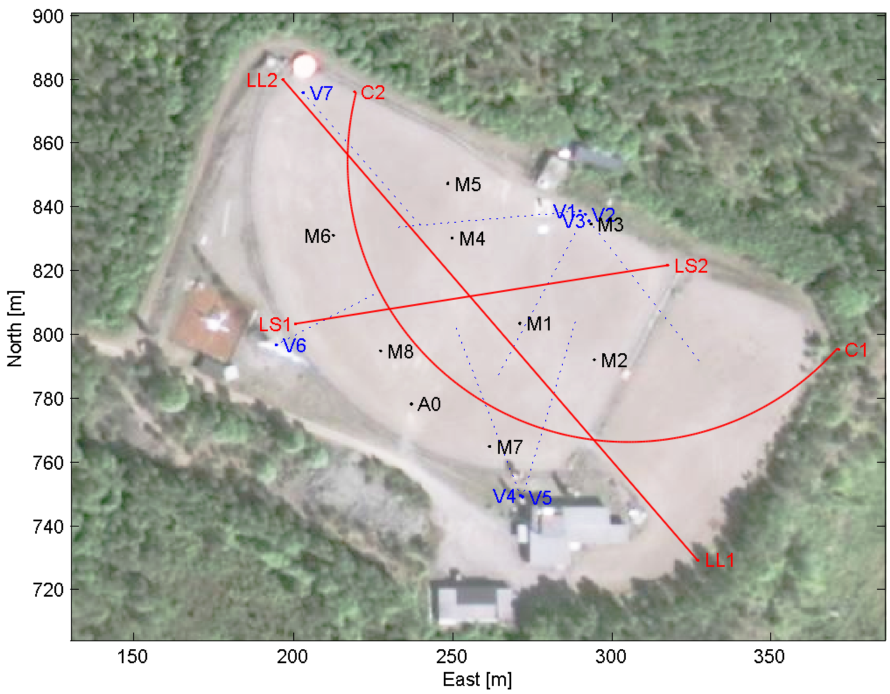


Figure 1: The Lilla Gåra test facility with indicated sensors positions and target paths for Experimental Setups I and II. Single microphones (black markers) are denoted M1–M8 and the acoustic array with A0. The visual cameras (blue) are denoted V1–V7, and their viewing direction is indicated with a dotted line. The shorter the line, the more downwards the camera is directed. The used target trajectories for the ground vehicles are given in red, where the label indicates the starting position.

(a) A single microphone

(b) The 4-microphone array

(c) A visual camera on a tripod

Figure 2: Illustration of the sensors used in the experiment.

2 Sensors

Measurement data is available from three different types of sensors: single microphones, a 4-microphone sensor array, and visual video cameras.

2.1 Sensor Hardware

This section describes the sensors used during the measurements campaign. The sensors will now be described:

Single microphone: The microphones used in the experiment are Brüel & Kjær model 4188, depicted in Figure 2(a). The microphones are designed to be reference microphones in an outdoor environment. The data was collected at 48 kHz with 16 bit precision. The eight single microphones, denoted M1–M8, were all placed approximately 0.2 m above the ground to minimize ground reflections.

4-microphone array: The microphone array consists of four of the single microphones carefully positioned in an perfect tetrahedron with 428 mm sides (see Figure 2(b)). The base of the tetrahedron was positioned 0.8 m above the ground plane. The array is denoted A0.

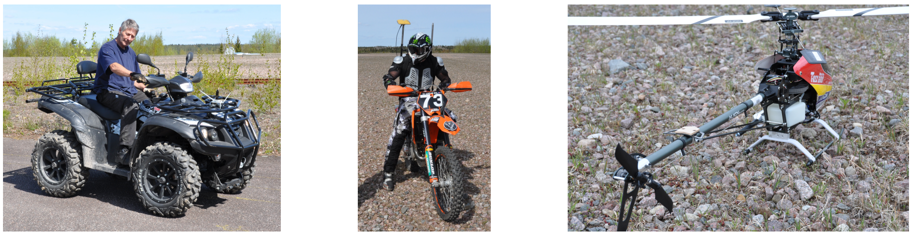
Visual camera: The visual cameras, denoted V1–V7, used in the experiments were Panasonic HDC-SD700 camcorder, recording at 50 Hz with a resolution of 1920 by 1080 pixel. The cameras were equipped with wide view lenses, providing approximately 70° horizontal field of view. The camera setup is illustrated in Figure 2(c).

2.2 Sensor Calibration

The exact locations of all sensors (the microphones and the cameras), were determined using a total station and an exact RTK GPS. The accuracy of the sensor positions is expected to be less than 0.1 m.

All microphones where pressure calibrated at the beginning of the experiment to allow for the sensors to be used for *received signal strength* (RSS) measurements.

All the camera-lens-combinations were furthermore calibrated, using several images with checker boards in them, to obtain their intrinsic camera cal-



(a) ATV (b) MC (c) RC helicopter

Figure 3: The three vehicles used in the experiment.

ibration. This was done using the "Camera Calibration Toolbox" [1] prior to deploying the cameras in the field.

The cameras then had their extrinsic calibration determined, when they were deployed. Again, this was done using the "Camera Calibration Toolbox" [1] and the known position of the clearly visible microphones and another 19 known positions distributed throughout the field.

3 Experimental Setups

Below, the different experimental setups and the experiments conducted are described.

3.1 Experimental Setup I

The first experiments were conducted on May 8, 2012. This was a warm calm day with clear skies and no rain. As a result of the warm dry weather, driving around on the gravel resulted in dust clouds that complicates the usage of the visual data. The background acoustic levels are characterized by: 51.0 dB SPL in the frequency interval 30–1000 Hz, divided into 50.7 dB SPL in the interval $30 - 150$ Hz and 38.6 dB SPL in the interval 150–1000 Hz. A few sporadic jet aircraft passages are audible, as well as, some low frequency disturbances most likely originating from the machinery at a close by quarrel.

For the experiment, nine single microphones, M1–M9, one acoustic array, A0, and seven camcorders, V1–V7, were used. Figure 1 shows how the sensors were distributed throughout the test field.

Two different targets were used in Experimental Setup I: an *all-terrain vehicle* (ATV) and a *motocross bike* (MC), depicted in Figures 3(a) and 3(b), respectively. The vehicles were at all the time equipped with GPS receivers which provide ground truth of the target trajectories.

The engines from both the vehicles emitted sound rich in harmonics. The ATV sound pressure 1 m from the vehicle *on-route* has been estimated to 110 dB SPL, and for the MC to 120 dB SPL.

The ground vehicles (the ATV and the MC) followed the trajectories marked with green lines in Figure 1. The drivers were asked to keep their speed steady at 30 or 50 km/h during the runs, and as far as possible with the same throttle to maintain an as steady engine sound as possible. The ATV and the MC ran the trajectories separately, as well as in some of the experiments at the same time to obtain a tight crossing of their paths. Table 1 summarizes the runs for which measurements are available.

Table 1: Experiments performed by the ground vehicles. The trajectories are denoted by their starting points (see Figure 1). In the combined cases no specific target speed was given, but rather the drives tried to accomplish a close crossing of the tracks. In terrorist trajectory the MC driver simulated a *rocket propelled grenade* (RPG) close to LS2, before taking of in full speed heading for LS1 but making a sharp turn and changed direction towards LL2.

Type	**Trajectory**	**Runs**	**Speed [km/h]**
MC	LL1	4	30
MC	LL2	4	30
MC	LL1	5	50
MC	LL2	5	50
MC	C1	4	30
MC	C2	4	30
MC	C1	4	50
MC	C2	4	50
MC	LS1	4	30
MC	LS2	4	30
ATV	LL1	4	30
ATV	LL2	4	30
ATV	LL1	4	50
ATV	LL2	4	50
ATV	C1	4	30
ATV	C2	4	30
ATV	C1	4	50
ATV	C2	4	50
ATV+MC	LL1+LS1	4	–
ATV+MC	LL2+LS2	4	–
ATV+MC	LL1+LS2	5	–
ATV+MC	LL2+LS1	5	–
MC (terrorist)	–	4	–

3.2 Experimental Setup II

The second set of experiments were conducted on May 9, 2012, with the same sensor configuration as day one (described in Section 3.1 and Figure 1). The second day of the measurement campaign was colder than the first day, the air was humid, with clouds in the sky, and during periods it rained. The rain removed the dust problem, but at the same time the clouds made the light conditions more difficult. The acoustic background level was 58.4 dB SPL in the frequency interval 30–1000 Hz, distributed as 57.9 dB SPL in the interval 30–150 Hz and 49.0 dB SPL in the interval 150–1000 Hz. The second day exhibited the same sporadic passing jet aircraft and the low frequency quarrel machinery disturbance.

The RC helicopter, shown in Figure 3(c) was used as the only target. Several different runs were conducted. The greater freedom of motion exhibited by the helicopter allowed for more different trajectories, hence, the trajectories are not as easily described as in the ground vehicle case, see Table 2. The RC helicopter produced a noise level of ?? dB SPL.

3.3 Experimental Setup III

The third experiment was performed on May 9, 2012, under the same weather and background noise conditions as described in Section 3.2. The experiment was performed using only nine single microphones spread out on the test field as illustrated in Figure 4.

Table 2: Trajectories performed by the RC helicopter. The same trajectories as with the ground vehicles were performed, at low and high altitude. Furthermore, data was collected from the helicopter hoovering, making loops over the field, as well as flying quickly randomly at low altitude.

Trajectory	Altitude	Runs
LL1	Low	9
LL2	Low	9
LL1	High	7
LL2	High	7
LS1	Low	3
LS2	Low	4
LS1	High	3
LS2	High	5
C1	Low	4
C2	Low	3
C1	High	4
C2	High	3
Hoovering	–	1
Loop 1	–	3
Loop 2	–	3
Loop 3	–	3
Quick	Low	3

Using this sensor network sound signals from several positions, as indicated with red dots and lines indicating the direction of the loudspeaker, are shown in Figure 4. At each position, three different sounds, an *orthogonal frequency division multiplexing* (OFDM) signal, a chirp, and birdsong from a Black-Throated Loon, where transmitted several times and the exact transmission time was recorded.

The OFDM and chirp had the center frequency 1000 Hz, a bandwidth of 500 Hz, and was transmitted in pulses of 0.3 s. The birdsong from the Black-Throated Loon had center frequency 1000 Hz, a bandwidth of 1200 Hz, and the pulses were slightly longer 0.9 s. The sound levels were 102 dB SPL, 109 dB SPL, and 106 dB SPL, respectively.

3.4 Experimental Setup IV

Experimental Setup IV differs only from Experimental Setup II, in the position of the microphones (see Section 3.3 for details). The new sensor positions are given in Figure 5.

Bibliography

[1] Jean-Yves Bouguet. Camera calibration toolbox for matlab, 2013. URL: `http://www.vision.caltech.edu/bouguetj/calib_doc/`.

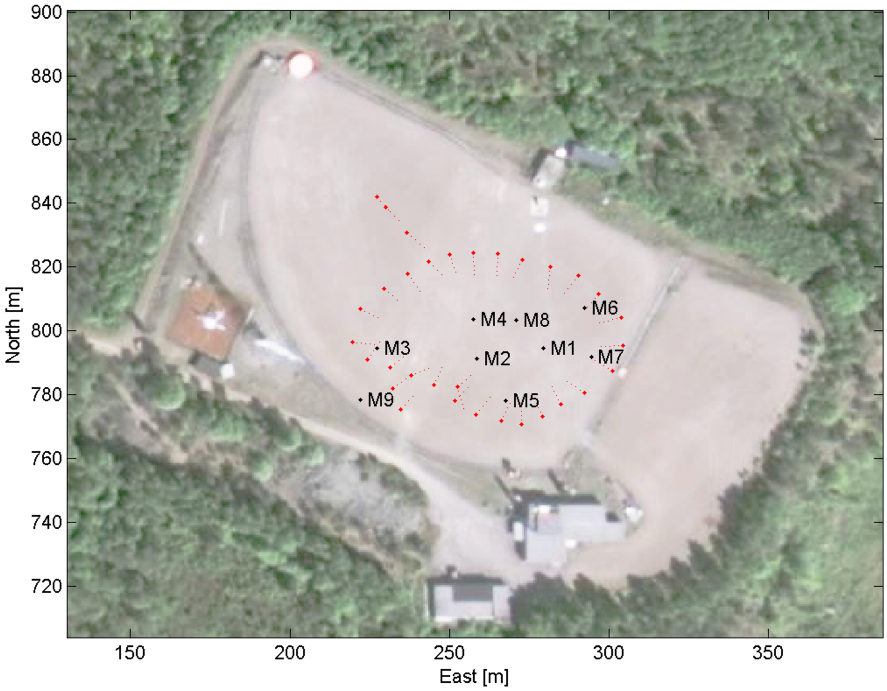


Figure 4: The Lilla Gåra test facility with indicated sensors positions for the second setup. Single microphones (black markers) are denoted M1–M9. The red dots indicate used sound source positions, and the short dotted line the direction the loudspeaker pointed.

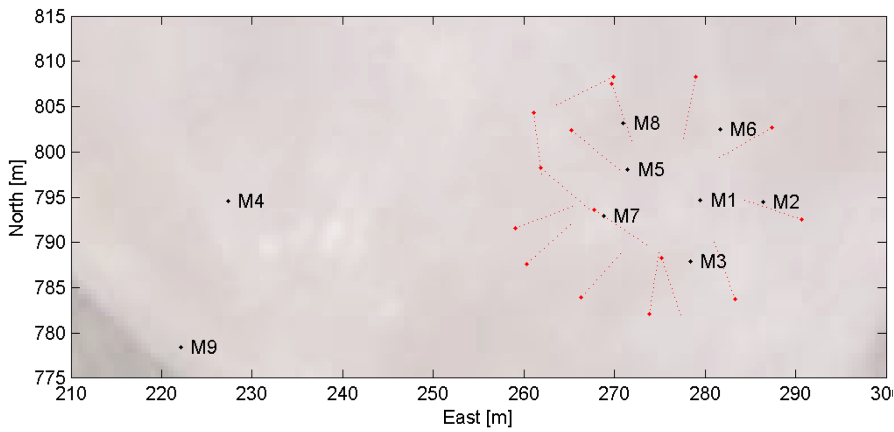


Figure 5: The Lilla Gåra test facility with indicated sensors positions for the second setup. Single microphones (black markers) are denoted M1–M9. The red dots indicate used sound source positions, and the short dotted line the direction the loudspeaker pointed.