Developing a Simulation and Hardware for a Robot Swarm Using Sound to Communicate

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In our research we are interested in getting a swarm of E-Puck [1] robots to communicate and cooperate with each other using audio messages. To perform these experiments we need a simulation of our robot swarm, as well as a hardware extension to the E-Pucks that is capable of detecting an audio signal and determining its frequency and the direction it came from. Robotic swarm experiments are enormously time consuming, so a simulation is needed to predict which experimental parameters are worth testing on a real robotic swarm.

1 Simulation

Our simulation was made following the CoSMoS process [2], which is an iterative design process for developing simulations of complex systems. CoSMoS consists of four deliverables. First there is the *Domain Model*. In simulation, the *Domain* is the thing we wish to model. In our simulation, the domain is E-Pucks with hardware that is still under construction. The *Domain Model* is an aggregation of everything we know about the domain. In our simulation this is the specification of the E-Pucks and the requirements for our custom hardware, everything else about the domain is still unknown. Second is the *Platform Model* which is everything we will use in our simulation from the domain model. We will simulate ideal E-Pucks with ideal custom hardware without attempting to add noise to their actions, this may need to be modified later if our simulation proves to be too innaccurate. Next there is the *Simulation* which is the implementation of the platform model. We will use Player/Stage, which is an open-source robot simulator [3]. The final deliverable is an *Analysis Model* which is the testing and verification of the model as it compares with the original domain. Since our domain involves robot hardware that has ot yet been built, we cannot yet verify our simulation against reality.

2 Hardware

To detect audio and the direction it came from, in the real robots, we will be using a *phased array* of microphones. Three or more microphones are evenly spaced along a plane, an approaching sound will reach each microphone at slightly different times. This delay is dependent on the angle the sound came from. If a sound originates from directly in front of the robot, it will hit the microphones at the same time. If it comes from 90° to the side there is the most delay between microphones receiving the sound. In a *phased array* we use this principle, but the process is reversed. We can effectively point the phased array of microphones in any direction by applying a delay to each microphone. This delay is calculated such that all the microphones will receive the sound at the same time only if the sound originates from the desired angle. If the delayed data from all the microphones is summed, this will give us a peak if the sound originates from the desired angle.

Our hardware records sound entering each microphone, the data is delayed and summed for 5 different angles. A Fourier transform is performed on each resulting waveform to give us a measure of which frequencies came from each angle.

3 Future Work

The next stage in our research is to finalise the hardware and test its limitations. Specifically we need to know its maximum range, the maximum frequency it can detect, its ability to measure a sound's direction and the minimum duration a sound can have for it to be detected. This information will be fed back into our simulation to improve its accuracy. Finally we will verify the simulation against a real robotic system performing basic audio communication.

References

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