Coordinated Actuation for Sensing Uncertainty Reduction

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Research Objective

We are interested in improving the sensing fidelity achieved using a given set of sensing resources, by aligning the network configuration precisely to the sensing requirements in the deployment environment. For example, consider a security application where cameras are deployed to monitor all humans present at a shopping mall. A naïve strategy would be to install enough sensors to cover the entire volume of the shopping mall at the resolution required for recognizing faces. However, if we consider the properties of the phenomenon being sensed, and realize that only a very small fraction of the volume actually consists of regions of interest (in this case, faces) we may be able to obtain the same sensing performance with significantly reduced sensor installation, maintenance and data processing costs. There are two major challenges in realizing this approach:

1. The sensing medium is deployment dependent and the presence of obstacles in the medium affect sensing. Further, the medium may even change over time after network installation.
2. The phenomenon distribution may be unknown a-priori and may vary over time. This hinders the determination of a static network configuration which can achieve the desired sensing performance with minimal resources.

To address these challenges, we are building a sensor network which reconfigures itself in response to the medium and the phenomenon using reduced complexity motion primitives. Sensing resources are autonomously focused on regions of interest, enabling high quality sensing with limited resources.

Description of Demonstration

In this demonstration, we address the issue of learning the medium characteristics to help orient the sensing resources optimally. The application sensors of interest are video cameras. The deployment environment models several indoor and outdoor environments where obstacles such as trees, furniture etc may be present. To learn the medium characteristics, we introduce a supplementary set of sensors, referred to as *self-awareness sensors*, which are used by the system internally to enhance its sensing performance but whose data output is not explicitly provided to the application. Note that this is different from multimode sensor fusion, such as using magnetic sensors in addition to image sensors for vehicle detection, since the self-awareness sensor data is never fused with the application sensor data for better estimation; rather the quality of application sensor data is improved. This keeps the use of self-awareness data independent of the application, and the fusion algorithm need not be domain specific.

In our system we use a laser range finder, mounted on a pan and tilt head as our self-awareness sensor. We demonstrate:

1. A complete sensor network including our application sensors (networked cameras with pan/tilt/zoom capability) and self-awareness sensors (laser range finder). These are placed in a model environment with several passive obstacles placed in the sensing medium.
2. Methods to relate the self-awareness sensor data to the sensing performance of the application sensors. Since both sensors are sensing in two different modalities, the raw data from one is not directly usable by the other. Specifically, we map the spatial coordinates in the medium sensed by the laser ranger to the pixel coordinates in the field of view of each camera in the shared medium, also accounting for camera calibration errors.
3. Example distributed methods to use the processed self-awareness data to configure the sensor orientations for optimal coverage. These methods are part of ongoing research.
4. A monitor process, which is not part of the sensor network but is executed to obtain sensor node states for evaluation purposes. This process visually represents the network-wide coverage performance at run-time.

A representative block diagram of our prototype appears below.

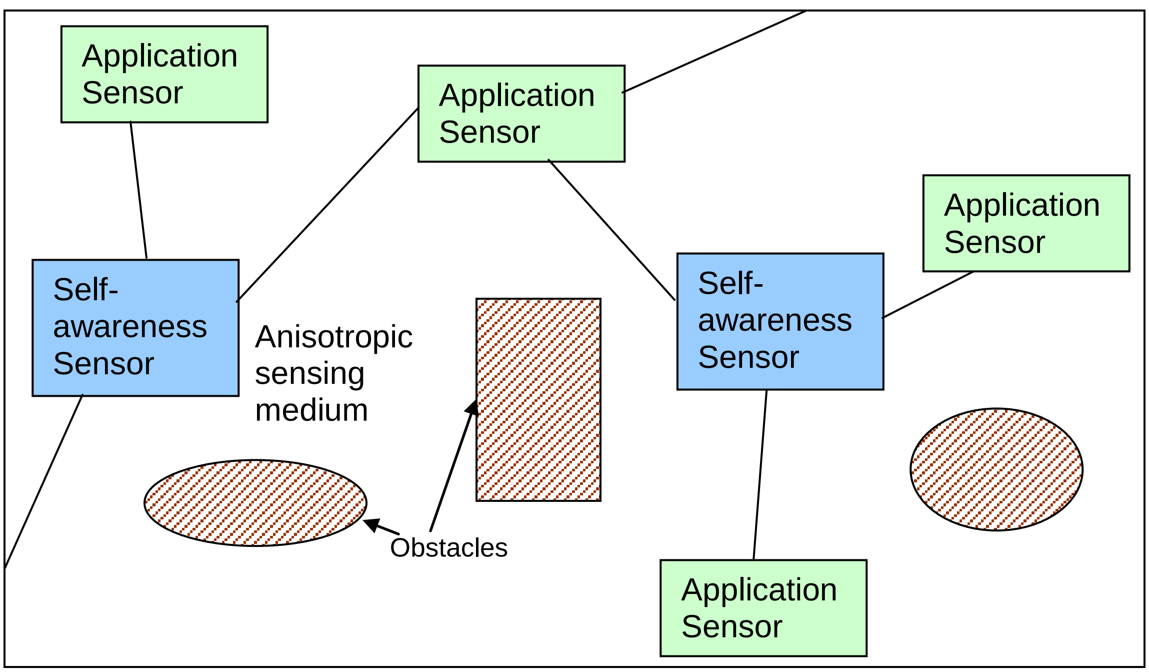

Fig 1. Block diagram of prototype sensor network with networked self-awareness sensors and application sensors.

The implementation is completely distributed and the different sensors are not controlled by a single process. Our prototype network integrates several components, such as Sony SNCrz30N network cameras, Leica Disto Laser ranger, and Intel X-scale based Stargate platform. Our software uses image processing methods, medium sensitive laser sampling algorithms and coordinated actuation algorithms.