Coordinating Camera Motion for Sensing Uncertainty Reduction

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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.

Consider an example: covering a shopping mall using surveillance cameras. Suppose a volume V1 is to be covered. Given a camera that can effectively cover a volume V2, we need approximately V1/V2 cameras. However, in typical applications, the entire volume V1 may not be of interest but only small portions of it (such as spaces containing human faces, for face recognition) may be required to be imaged. This volume is a very small fraction, p, of V1, reducing the number of cameras required to pV1/V2. This reduction is possible only if the cameras can be adaptively moved to orient towards the interesting regions. In many applications, detecting regions of interest, such as humans, is possible using a low resolution image (such as detecting motion for detecting potentially interesting regions where humans may be present) or alternative forms of sensors. We develop methods which use this low resolution side information to adaptively control the motion of deployed cameras such that a smaller number of cameras, pV1/v2 can achieve the effective coverage of V1/V2 cameras.

In particular, we address the following issues in our prototype:

1. The sensing medium is deployment dependent and the presence of obstacles in the medium affect sensing. Our system includes special sensors to characterize such obstacles, and this information is used at run time for controlling camera orientation.

2. The use of motion has several resource overheads and presents system design challenges which may outweigh the savings in number of sensors. Hence, we explore the use of low-complexity motion primitives, such as pan, tilt and zoom in cameras. This choice is based on our analysis of trade-offs in using different forms of motion or a high density of static nodes.

3. The phenomenon distribution may be unknown a-priori and may vary over time. This hinders the determination of a static network configuration before deployment. Hence, we present methods to detect regions of interst using low resolution data, which guide the motion control algorithms at run time.

4. Finally, we demonstrate our motion control algorithms which continuously adapt system configuration to the sensing demands. (These are in addition to any methods used for planning the node locations before deployment.)

The implementation is completely distributed and all methods presented have been designed to ensure scalability to large numbers of nodes.

Our prototype network integrates several components, such as Sony SNCrz30N network cameras, Leica Disto Laser rangers, and Intel X-scale based platforms. Our software implements our proposed image processing methods, medium sensitive laser sampling algorithms and coordinated motion algorithms. All the software developed for our prototype system are open source and available for download; some of these are already being used at other universities for sensor network development.