Title:
Poster Abstract: Entropy-based Sensor Selection in Localization

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ABSTRACT
We propose a novel entropy-based sensor selection heuristic for localization. Given 1) a prior probability distribution of the target location, and 2) the locations and the sensing characteristics of a set of additional sensors, we would like to select an optimal additional sensor such that fusion of its measurements with existing information would yield the greatest entropy reduction of the target location distribution. The heuristic can select a sub-optimal additional sensor without retrieving the measurements of candidate sensors. The heuristic is computationally much simpler than the mutual information based sensor selection approaches for localization and tracking [1, 2]. Just as those existing approaches do, the heuristic greedily selects one sensor in each step.

Categories and Subject Descriptors
H.1.1 [MODELS AND PRINCIPLES]: Systems and Information Theory—Value of information

General Terms
Algorithms

Keywords
sensor selection, localization, wireless sensor networks

1. INTRODUCTION
There have been many investigations of information-theoretic approaches to sensor fusion and management. The idea of using information theory in sensor management was first proposed in [3]. Sensor selection based on expected information gain has been introduced for decentralized sensing systems in [4]. The mutual information between the predicted sensor measurements and the target location distribution has been proposed to evaluate the expected information gain of incorporating a sensor in [1, 2]. The dependency of the localization uncertainty on the sensor locations relative to the target location has been identified during the development of localization algorithms without using information theory [6]. One example is the convex hull heuristic of localization using time-difference-of-arrival (TDOA) sensors. Targets inside the convex hull of TDOA sensors can be much more accurately located than those outside the convex hull. We propose a novel entropy-based heuristic for sensor selection based on our experiences with target localization. It is computationally more efficient than mutual information based methods proposed in [1, 2].

We use the following notations throughout this poster:
(1) \( x \) is the random variable for the target location, \( x_t \) is the true target location, \( \hat{x} \) is the maximum likelihood estimate of the target location,
(2) \( z_i \) is the random variable for the observation of sensor \( i \), \( z_i^* \) is the view of sensor \( i \) about the target location,
(3) \( x_i \) denotes the deterministic location of sensor \( i \).

2. SENSOR SELECTION HEURISTICS
The sensor selection problem discussed in this poster can be formally defined as follows. Given
(1) the prior target location distribution: \( p(x) \),
(2) the locations of additional sensors: \( x_i, i \in S \),
(3) the sensing models of additional sensors: \( p(z_i|x), i \in S \),
the objective is to find the additional sensor \( i \) whose measurements \( z_i \) minimizes the conditional entropy of the posterior target location distribution,
\[
\hat{i} = \arg \min_{i \in S} H(x|z_i). \tag{1}
\]

Equivalently, sensor \( \hat{i} \) maximizes the expected target entropy reduction,
\[
\hat{i} = \arg \max_{i \in S} (H(x) - H(x|z_i)). \tag{2}
\]
\( H(x) - H(x|z_i) \) is one expression of \( I(x; z_i) \), the mutual
information between the target location $x$ and the sensor measurements $z_i$. Thus, using the definition of $I(x; z_i)$,

$$
\hat{i} = \arg \max_{i \in S} \int p(x, z_i) \log \frac{p(x, z_i)}{p(x)p(z_i)} \, dx \, dz_i. \tag{3}
$$

[1, 2] propose to select the sensor with maximum $I(x; z_i)$. $I(x; z_i)$ is computed using the predicted $p(z_i)$ based on $p(x)$ and $p(z_i|x)$ without obtaining the actual measurement of $z_i$. However, $I(x; z_i)$ could be computed multiple times if the sensing uncertainty does not change with time. Therefore, the heuristic defined in (7) is much more efficient than the method using mutual information defined in (3).

3. RESULTS, CONCLUSION, AND FUTURE WORK

We have evaluated the above described sensor selection heuristic by using target localization simulations. The heuristic is much simpler to compute than mutual information. More details can be found in [5]. This poster presents the case study of sensor selection for localization using DOA sensors. We plan to implement the method on a real-time wireless sensor network testbed for localization.

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5. REFERENCES


