Distributed RSS-AoA Based Localization With Unknown Transmit Powers

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***Abstract*—This letter addresses the hybrid range/angle-based target localization problem in a cooperative 3-D wireless sensor network where no central processor is available. Due to battery exhaust over time, sensors' transmit powers are assumed different and unknown. Range and angle measurements are drawn from the received signal strength and angle-of-arrival models, respectively. By exploiting the measurement models, we derive a novel local-estimator by which each target updates its own estimate, based on the least squares criterion. Second-order cone relaxation technique is then applied to approximately solve the attained problem due to its non-convex nature. Our simulation results show that the proposed algorithm efficiently solves the localization problem.**

***Index Terms*—Wireless localization, distributed localization, received signal strength (RSS), angle-of-arrival (AoA), second-order cone programming (SOCP), wireless sensor network (WSN).**

I. Introduction

LOCALIZATION has become an active research area in recent years owing to emerging services based on location-awareness in a myriad of wireless structures [1], [2]. Wireless localization algorithms commonly rely on range measurements [3], [4], extracted from time-of-arrival, received signal strength (RSS), angle-of-arrival (AoA), or a combination of them.

Significant progress has been made in developing centralized range/angle localization algorithms, for both non-cooperative [5]–[8] and cooperative localization [9]. In [5], linear least squares (LS) and optimization based estimators were studied. An LS and a maximum likelihood (ML) estimators for a hybrid scheme that merges RSS difference (RSSD) and AoA measurements were derived in [6] by employing non-linear constrained optimization. In [7], a selective weighted LS (WLS) estimator for RSS/AoA localization problem was proposed. Another WLS estimator for RSSD/AoA localization problem was presented in [8]. An estimator based on semidefinite relaxation technique where triplets of points were used to obtain the angle measures was proposed in [9].

All of the above approaches offer a centralized solution to the hybrid range/angle localization problem. Although centralized approaches are stable, in large-scale networks, a central processor with enough computational capacity might not be available. Hence, a distributed solution is of practical interest.

In this letter, we investigate a hybrid RSS/AoA localization problem in cooperative wireless sensor networks (WSNs). Due to battery exhaust over time, we consider the scenario where the sensors' transmit powers are different and unknown. Furthermore, the case where the path loss exponent (PLE) is different for each link and not perfectly known is examined. For such a challenging localization problem, we propose a distributed solution based on second-order cone relaxation (SOCR) technique. The proposed algorithm requires no central processor and has a computation-free initialization. To accomplish a completely distributed algorithm, information exchange is allowed between two incident sensors exclusively and data processing is performed locally by each sensor.

II. Problem Formulation

Consider a large-scale WSN with a set of anchors $|\mathcal{A}| = N$ (sensors with known locations) and a set of targets $|\mathcal{T}| = M$ (sensors whose locations are to be determined), where $|\bullet|$ represents the cardinality of a set. We denote the locations of the referred sensors as $\boldsymbol{a}_j \in \mathbb{R}^3, \forall j \in \mathcal{A}$ and $\boldsymbol{x}_i \in \mathbb{R}^3, \forall i \in \mathcal{T}$, respectively. Two sensors are linked if and only if they are within the communication range, R, of each other. Hence, the sets of all target/anchor and target/target links are respectively defined as $\mathcal{L}_{\mathcal{A}} = \{(i,j) : \|\boldsymbol{x}_i - \boldsymbol{a}_j\| \leq R, \forall i \in \mathcal{T}, \forall j \in \mathcal{A}\}$ and $\mathcal{L}_{\mathcal{T}} = \{(i,j) : \|\boldsymbol{x}_i - \boldsymbol{x}_j\| \leq R, \forall i,j \in \mathcal{T}, i \neq j\}$.

A hybrid system which merges range and angle measurements is employed to determine the unknown locations of the targets, as shown in Fig. 1. In Fig. 1, $\boldsymbol{x}_i = [x_{i1}, x_{i2}, x_{i3}]^T$ and $\boldsymbol{a}_j = [a_{j1}, a_{j2}, a_{j3}]^T$ are respectively the coordinates of the i-th target and the j-th anchor, while $d_{ij}^{\mathcal{A}}$, $\phi_{ij}^{\mathcal{A}}$ and $\alpha_{ij}^{\mathcal{A}}$ represent the distance, azimuth angle and elevation angle between the i-th target and the j-th anchor, respectively.

We assume that the distances are drawn from the RSS measurements, since ranging based on RSS requires no additional hardware. The noise-free RSS between two sensors, i and j,

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