An Auction-Bidding Protocol for Distributed Bit Allocation in RSSI-based Localization Networks

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***Abstract*—Several factors (e.g., target energy, sensor density) affect estimation error at a point of interest in sensor networks. One of these factors is the number of allocated bits to sensors that cover the point of interest when quantization is employed. In this paper, we investigate bit allocation in such networks such that estimation error requirements at multiple points of interest are satisfied as best as possible. To solve this nonlinear integer programming problem, we propose an iterative distributed auction-bidding protocol. Starting with some initial bit distribution, a network is divided into a a number of clusters each with its own auction. Each cluster head (CH) acts as an auctioneer and divides sensors into buyers or sellers of bits (i.e., commodity). With limited messaging, CHs redistribute bits among sensors, each bit at a time such that the difference between achieved and required estimation errors within each cluster is reduced in each round. We propose two bit-pricing schemes used by sensors to decide on exchanging bits. Finally, simulation results show that our proposed 'distributed' protocol's error performance can be within $5\% - 10\%$ of that of a 'centralized' genetic algorithm (GA) solution.**

***Keywords*—Target localization; Auction-bidding**

I. Introduction

A Distributed sensor network (DSN) consists of a large number of sensors deployed in a region of interest (ROI) with the main task of monitoring certain phenomenon in the ROI [1], [2]. With their ability to continually monitor in harsh and hostile environments with limited human intervention, DSNs bridge the gap between the physical world and our computational world. DSNs have found uses in many fields such as; environmental, industrial, agriculture and defense. However, in many cases it is not sufficient to monitor the phenomenon (e.g., fire) and detect its presence. It might be also necessary to identify the coordinates of the source of the phenomena (i.e., target localization) in order to take meaningful action (e.g., fire control) [3]-[6].

Target localization in general is a nonlinear estimation problem [7]-[9], in which sensors send their nosy data to a fusion center that employs some estimator (e.g., ML estimator) to determine location information. The problem's nonlinearity arises from the nonlinear relationship between sensor measurements (e.g., received signal strength (RSSI) and time difference of arrival (TDOA)) and target location. RSSI measurements are commonly used due to the simplicity of obtaining them in comparison to other types.

In RSSI-based localization, error performance is dependent on several factors. These include; sensor positions with respect to target, target-related parameters (e.g., energy profile), measurement model [10], [11]. Moreover, in practical networks with imposed bandwidth and energy limits, measurement quantization is usually employed. In such a case, the localization error performance further depends on both the number of bits allocated to each sensor and the quantization thresholds used [12].

Due to the complicated relationship between the above mentioned parameters and the error performance, it becomes important to devise intelligent methods for bit allocation in RSSI networks. Furthermore, and due to the large number of sensors typically found in DSN, it is important for bit allocation to be scalable and easy to implement.

We state the problem we study in this paper as follows; Given a network of M sensors deployed in an ROI that contains multiple points of interest with corresponding estimation error requirements and having some given initial bit allocation distribution, how can we re-allocate these bits in a "distributed" fashion such that error requirements at the points of interest are met as best as possible?. To solve this problem, propose a novel distributed bidding/auction protocol for bit re-allocation. Next, we provide an overview of some related works to the bit allocation problem in RSSI-based localization networks.

In [13], an iterative two-stage algorithm for bit allocation and threshold selection is proposed with the goal of minimizing the average overall error. The first stage deals with the reconstruction of the quantized sensor measurement at the fusion center (FC). The second part is concerned with the error between the actual location of the target and its estimated location. We note that the proposed algorithm constructs the quantizer using a training data set according to some given probability distribution of the target's possible location. In addition, the authors propose a simple equal distance divided quantizer (EDQ) for threshold selection, where each quantization interval corresponds to a quantization ring within the sensor field.

More recently, in [14] and [15], the authors propose several bit allocation methods for the target tracking problem with the goal of minimizing estimation error. As a cost function, the authors use the determinant of the Fisher information matrix (FIM). To solve this problem, the authors propose an 'approximate' recursive dynamic programming (A-DP)

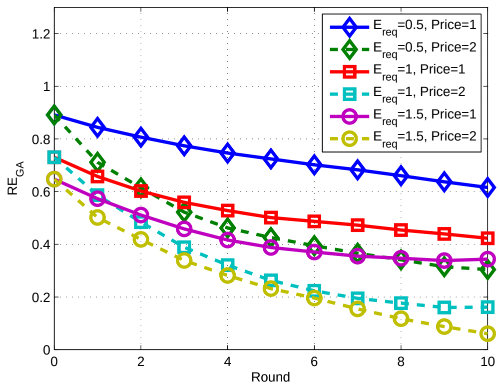
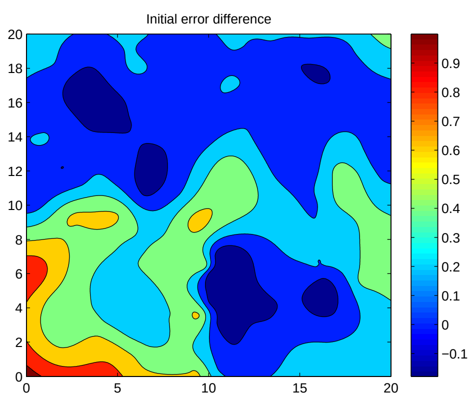
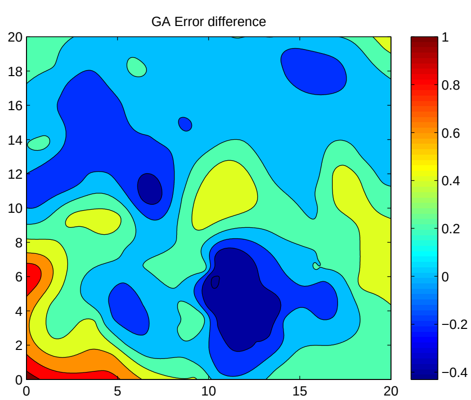


Fig. 7: $RE_{\text{GA}}(k)$ vs. rounds for different requirements

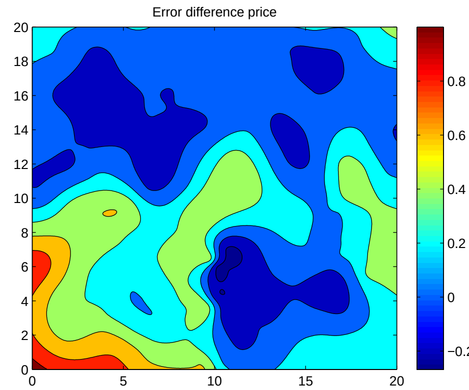


(a) Initial

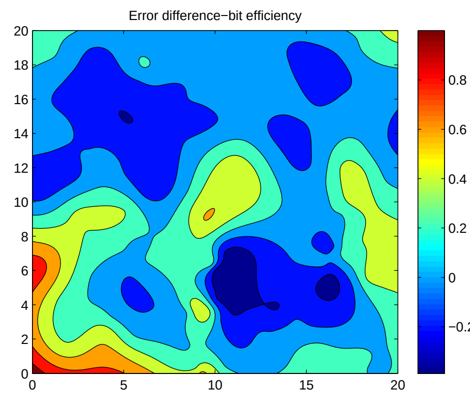


(b) GA

Fig. 8: Initial and GA error difference distribution



(a) Error difference price



(b) Error-Bit efficiency price

Fig. 9: Error distribution using proposed protocol

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