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Object positioning is an important research which has been applied in many application areas for decades. Usually, a number of spatially separated observers capture a set of range or angle based measurements, and then estimate the object location based on the measurements. The problem is not trivial because of the high non-linearity between the measurements and the object position. The performance of a localization system mainly depends on two factors. One is the measurement type and the other is the estimator which explores the non-linear measurement equations to estimate the object position. This research investigates the positioning techniques from these two aspects.

First, we analyze the localization performance of the common positioning approaches, such as time of arrivals (TOA), time differences of arrival (TDOA) and angle of arrivals (AOA). We theoretically derive the biases of their Maximum Likelihood (ML) object location estimates resulted from the Gaussian measurement noise and observer position errors. The derived formulas show that the two types of errors contribute inter-related bias components unless they are independent and identically distributed (IID). The bias behaviors of the three positioning approaches are contrasted and the geometric conditions under which the location bias becomes zero are elaborated. The effectiveness of the developed results for bias compensation in improving the performance of object tracking is illustrated. The study is then extended to elliptic positioning, which is recently received attentions because of its asynchronous operation capability. We characterize its performance with respect to TDOA based on the Cramer-Rao Lower Bound (CRLB) and the bias of the ML object location estimate under Gaussian measurement noise as well as transmitter and observer position errors. When the observer positions are controllable, we derive its optimum observer placement to improve the localization accuracy. Its performance study is demonstrated by simulation.

Second, we propose efficient solutions for three challenging positioning problems. The basic idea is to use parameter transformation and multi-stage processing to convert the original non-linear estimation problem into multiple sequential linear estimation problems. One example is the joint localization and synchronization problem in a wireless sensor network (WSN) when Gaussian beacon position and clock uncertainties are present. Two computationally efficient closed-form algorithms are developed to explore the time stamp information from message exchanges within the WSN. One is for the case without message exchanges among the sensor nodes and the other is with the exchanges. The proposed algorithms are proved by theoretical analysis and simulations to reach the CRLB accuracy for the sensor node positions and the clock parameters over the mild error region. The second problem addressed is the multistatic sonar localization when the uncertainties in the signal propagation speed and the transmitter and receiver positions are present. The proposed efficient algorithms for this problem obtains the hybrid CRLB over the mild error region as shown by the analysis and simulation. The last problem is for object localization in the relay network. Comparing to traditional problems, additional ambiguity exists because the measurements are collected along time without the knowledge of their corresponding relays . An Markov Chain Monte Carlo method, Metropolis-Hastings algorithm, is applied to solve the measurement association problem to avoid the high computation burden in the traditional brute-force method. The ML object location estimate is iteratively obtained by the alternating minimization principle. The proposed method has shown good performance under the mild noise level in the simulation.