Chapter 6
Conclusions

Target localization and tracking are critical in ubiquitous computing systems and technologies. Although localization and tracking in outdoors have been significantly improved in the last years due to the wide adoption of GPS, in indoors they still attract significant R&D interest. A very high variety of localization and tracking approaches, techniques and technologies have been developed in the recent years. However, none of the proposed sensors, techniques or systems is ideal for all the problems and the selection of the method highly depends on the specific requirements and constraints of the application and of the environment.

Clustering is the most widely employed and researched approach in target localization and tracking in ubiquitous computing systems. Clustering naturally solves scalability and simplifies computation and communications. Besides, it is resource-efficient since only the nodes that participate in target localization and tracking are kept active and the rest are left inactive in low energy mode. Cluster-based localization and tracking systems should deal with three main tasks: measurement integration, node inclusion/exclusion in the cluster and selection of the cluster head.

This book summarized the current state of the art in cluster-based localization and tracking in ubiquitous computing systems. It presented the main architectures, techniques and technologies. This book also summarized the main existing techniques that deal with these three issues: measurement integration, node inclusion/exclusion and cluster head selection.

This book also presented a general architecture for cluster-based tracking. The architecture comprises modules that deal specifically with the three aforementioned issues. The book also briefly presented different distributed information-driven techniques suitable for each of these issues. All these techniques are fully distributed and require the active cooperation of all the nodes within the cluster. They use distribution-friendly tools and metrics, are efficient in the consumption of energy and computational resources and can be executed in almost constant time regardless of the cluster size.

J.R. Martínez-de Dios et al., *Cluster-based Localization and Tracking in Ubiquitous Computing Systems*, SpringerBriefs in Cooperating Objects,
DOI 10.1007/978-3-662-54761-8_6

The techniques and schemes described in this book should be interpreted as a step in a longer-term research effort. The developed techniques and schemes and their operation in real applications open new questions and new research lines that still have not been sufficiently covered.

Cluster-based schemes naturally fit multi-target tracking since each target has its own cluster. However, the presence of several targets requires methods and schemes that specifically address target cross-tracking, cluster collisions and cluster merging, among others. Although some techniques have been proposed, they are too specifically suited to specific problems. The development of flexible, general and efficient techniques to solve these issues opens wide fields for research.

Multi-target multi-sensor localization and tracking requires techniques to solve the association of measurements. Association of RSSI and camera measurements can be addressed for instance using face recognition techniques to identify people or tagging the targets with visual markers that can be detected using computer vision. Also, some measurement association techniques based on voting and establishing local associations using different distance metrics have been developed. However, these solutions are usually very suited to the particular problem and the general data association problem is still far to be solved.

A real-world application has to be reliable and secure. Most of the developed techniques do not consider techniques or protocols to ensure packet delivery or to encrypt the data exchanged. For instance, the loss of packets that notify the decisions taken by the node inclusion/exclusion or cluster head selection methods can involve severe degradation in tracking performance. Lightweight protocols that ensure and confirm the reception of these packets should be implemented. On the other hand, the deployment of sensor nodes in an unattended environment makes the networks vulnerable to a high variety of potential threats. It is of high relevance to protect the network and ensure data integrity and confidentiality. Of course, the integration of such techniques can affect the performance of the system, increasing the computational burden and the number of interchanged packets. Therefore, a suitable trade-off between security and performance must be sought.