Chapter 9

Navigation Based on Sensors in Smartphones

Guenther Retscher  
TU Wien, Austria

Allison Kealy  
RMIT University, Australia

ABSTRACT

With the increasing ubiquity of smartphones and tablets, users are now routinely carrying a variety of sensors with them wherever they go. These devices are enabling technologies for ubiquitous computing, facilitating continuous updates of a user’s context. They have built-in MEMS-based accelerometers for ubiquitous activity monitoring and there is a growing interest in how to use these together with gyroscopes and magnetometers to build dead reckoning (DR) systems for location tracking. Navigation in complex environments is needed mainly by consumer users, private vehicles, and pedestrians. Therefore, the navigation system has to be small, easy to use, and have reasonably low levels of power consumption and price. The technologies and techniques discussed here include the fusion of inertial navigation (IN) and other sensors, positioning based on signals from wireless networks (such as Wi-Fi), image-based methods, cooperative positioning systems, and map matching (MM). The state-of-the-art of MEMS-based location sensors and their integration into modern navigation systems are also presented.

INTRODUCTION

Modern smartphones are equipped with a large number of sensors, including Global Navigation Satellite Systems (GNSS), Wireless Fidelity (Wi-Fi; a.k.a. WLAN), Bluetooth, accelerometers, magnetometers, cameras, microphones, and health monitors. These sensors are natural candidates for sensing the context in which a user is situated. Automatic access to such context information can be exploited towards localization. The increasing ubiquity of location-aware devices, fueled by the consumer smartphone market has pushed the need for robust GNSS-like positioning capabilities in GNSS difficult environments. In particular, Micro-Electro-Mechanical Systems (MEMS) technology has revolutionised user localization and MEMS inertial sensors and systems have become indispensable to the future of navigation. Navigation...
Navigation Based on Sensors in Smartphones

itself has become much broader than just providing simple solutions to LBS (Location Based Services) queries such as “Where am I?” or “How to get from a start point A to a destination B?” It has moved into new areas such as games, geolocation, mobile mapping, virtual reality, tracking, health monitoring and context awareness. These functionalities are being further enhanced by ongoing progress in MEMS technology. Their small size, low power and weight, and low cost have led to increased use, new applications, increased mobility, increased integration (hence better performance) and extended operation. When integrated with GNSS and other sensors, the integrated system enhances the localization performance in GNSS denied environments where the satellite signal is either totally blocked or attenuated. The combination of the two systems exploits their complementary characteristics. These integrated navigation technologies and methods have become indispensable in many applications like car navigation, human motion modelling, first-responder personal navigation, UAV (Unmanned Aerial Vehicle) navigation, and portable navigation. In this chapter the emphasis is on applicability and performance for navigation of a mobile client. It provides details of the performance capabilities of MEMS-based sensors in combination with wireless positioning technologies for localization of a mobile client and gives indicative performance levels as well as inherent limitations. It is emphasised that no single sensor or technique is currently able to meet the stringent positioning requirements for the increasing number of safety and liability critical mass market applications. Integration and sensor fusion of MEMS and wireless technologies is a necessity to guarantee an acceptable level of performance. Thus, this chapter reviews the range of MEMS sensors and wireless positioning techniques available in current mobile devices, such as smartphones and tablets.

The chapter is structured as follows: Firstly, the background of MEMS sensor technology is briefly discussed followed by a detailed description of the operational principle of MEMS-based location sensors. Then, individual sensors based localization techniques and systems are described, including dead reckoning (DR), inertial navigation (IN), map matching and Kalman filtering for continuous user localization. Also, activity detection and altitude determination using barometric pressure sensors are studied. Next, the combination with other techniques, such as wireless options (Wi-Fi and Bluetooth) and vision-aided sensors (digital cameras), are discussed. Sensor fusion techniques and cooperative positioning are briefly studied. Finally, a brief description of typical applications, i.e., pedestrian and vehicle navigation is presented, and a summary concludes this chapter.

MEMS-BASED LOCATION SENSORS

MEMS are miniaturized mechanical and electro-mechanical devices and structures that are made using micro-fabrication techniques. They integrate electrical and mechanical components with feature sizes in the micrometer-scale, which can be fabricated using integrated circuit batch-processing technologies (Gad-el-Hak, 2001). MEMS have allowed the development of several microdevices such as accelerometers (Li et al., 2011a), gyroscopes (Che et al., 2010), micromirrors (Li et al., 2011b), and pressure sensors (Mian and Law, 2010). The physical dimensions of MEMS devices can range from below 1 μm to several mm. The types of MEMS devices vary from relatively simple structures having no moving elements, to complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. MEMS assembly involves joining two or more components to form a MEMS device. A basic requirement of automated micro-assembly is that the system must be able to transport micro-scale parts and components and to manipulate them so that precise spatial relations