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Letter from the Guest Editor - Approaching an Ubiquitous Positioning Solution for Indoor Navigation and Location-Based Service

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This special issue is a collection of the ten best papers selected from the proceedings of the IEEE conference "Ubiquitous Positioning, Indoor Navigation and Location-based Service" held in Helsinki, 14-15 Oct. 2010. The selected papers cover several interesting topics including the visual-aided navigation, multipath mitigation for indoors, indoor pedestrian navigation, PDR (Pedestrian Dead Reckoning) with EMG (Electromyography) sensors, and indoor positioning using wireless sensor networks.

Most smart phones are embedded with navigation sensors such as GNSS (Global Navigation Satellite System) receiver, accelerometer, digital compass, and gyroscope. These sensors are enabling technologies for Location Based Service (LBS), such as pedestrian navigation, car navigation and augmented reality. Navigation now becomes a standard function in most smart phones. It brings new experience to the mobile users. However, a reliable position is the starting point of all these applications. A wrong coordinate can confuse the user on busy roads, in the deep forestry and cause panic and even danger Locate a mobile phone in open areas with an accuracy of a few meters is not the difficult task using the current GNSS technology such as GPS (Global Positioning System). However, it is still a very challenge task to locate the mobile user with sufficient accuracy in the GNSS signal degraded environments such as urban canyons, deep forestry foliage and indoors. For these challenge environments, additional sensors such as accelerometers, digital compass and gyros are commonly adopted to augment the GNSS solutions. For indoors, signals of opportunity from short range RF (Radio Frequency) technologies such as WLAN (Wireless Local Area Network), Bluetooth and RFID (Radio Frequency Identification) are also being employed to locate mobile users.

In the portfolio of the ubiquitous positioning solutions, there are four positioning approaches depending on positioning environments and accuracy: the GNSS-based solution, the RAN (Radio Access Network)-based solution, the solution based on signals of opportunity and the hybrid solution.

The GNSS-based solution is the most common solution for outdoors. In addition to the meter level positioning accuracy, GNSS is a cost-effective and mature positioning solution for a wide range of applications in addition to smart phone applications. The disadvantage of the GNSS-based solution is that it is not able to provide any useful positions for indoors although some signals may be received with a high sensitivity receiver. The positioning availability is rather low in signal degraded environments such as urban canyons and forestry foliages in addition to the degradation of positioning accuracy. This situation is now being improved via the deployments of new GNSS systems including the European system Galileo and the Chinese system COMPASS. The number of satellites visible in urban canyon will be triple. The positioning availability will be improved significantly though we may not be able to improve the positioning accuracy much because of the poor geometry. The Russian system GLONASS (GLObalnaja NAvigatsionnaja Sputnikovaja Sistema) is now being adopted for consumer class receivers as well. It will further improve the position availability and accuracy.

In addition to the GNSS-based solution, a mobile phone can also be located using Radio Access Networks (RAN) such as the CDMA (Code Division Multiple Access) networks; the GERAN (GSM/EDGE Radio Access Network) networks and the UTRAN (UMTS Terrestrial Radio Access Network) networks. The positioning accuracy of the RAN-based solutions ranges from 100 meters to kilometers. The common measurements used in the RAN-based positioning solutions are the signal coverage area, signal strength, angle of arrival, time of arrival and time difference of arrival. The most common positioning solutions include the Cell-ID or Enhanced-Cell ID solution and the trilateration solution using the measurements of the time-difference of arrivals. The RAN-based solution works for both indoors and outdoors.

While the RAN-based positioning works in wide areas, WLAN and Bluetooth signals of opportunity offer positioning solutions in local areas utilizing the RF signals available for smart phones. Although these signals were originally designed for the purpose of short range wireless communications, they have been widely adopted for positioning purpose because of the fact that the signal strength is an indicator of the distance between the signal transmitter and receiver. For this reason, the most common measurement used for positioning is the Received Signal Strength Indicator (RSSI). The most common positioning solution is the fingerprinting solution, though the Cell-ID solution and the trilateration solution are also used for some cases. The fingerprinting solution works in two phases: the data training phase and the positioning phase. The training phase includes the steps of generating a fingerprint database for the targeted area using the RSSI training samples, while the positioning phase includes the steps of finding a location by matching the snapshot of the real-time RSSI measurements to a fingerprint set stored in database. The RSSI matching process can be implemented with a simple pattern recognition approach or a probabilistic approach e.g. the Bayesian estimation.

Although the RAN-based solution works for both indoors and outdoors, the positioning accuracy is too low for most applications. The GNSS-based solution works fine for outdoors, but it does not work properly for indoors and signal challenge environments. The solution based on signals of opportunity works for indoors, but only for a limited signal coverage area. None of these solutions alone can provide a seamless positioning solution from outdoors to indoors. A hybrid solution of integrating multiple sensors and multiple signals of opportunity is the hope for achieving this goal. The sensors include GNSS receivers, accelerometers, gyros, and digital compass, while the signals of opportunity include the RF-signals from WLAN (Wireless Local Area Network), Bluetooth signal and RFID (Radio Frequency Identification). These sensors and signals of opportunity are typically available in smart phone though most of them are not originally designed for positioning purpose. GPS/INS (Inertial Navigation System) integration and PDR (Pedestrian Dead Reckoning) are typical approaches for fusing data from different sensors and RF networks. In this hybrid integrated solution, the GNSS receiver and the short range RF signals are the origins of data sources for absolute positioning, while other sensors are that for relative positioning. The absolute positions are used to calibrate the inertial sensors so that they can be used for providing positions during an outage of the absolute positioning sensor e.g. the GPS outage under a tunnel. For indoors, some sensors such as the digital compass are sensitive to the ambient environment. It is easy to get a heading error of a few tens of degrees with the digital compass embedded in smart phone. Visual-aided navigation is now becoming a hot research topic in the scientific community because camera is not affected by the ambient environment. However, the lighting condition is crucial for indoors to obtain a high quality image, which is the starting point for image-based positioning. Another important issue is the computation load for image processing, which is a critical issue for smart phone. A few papers have been selected in this special issue to address this interesting topic.

There is no doubt that the hybrid approach is the future for ubiquitous positioning. The future directions cover two aspects: new sensors/RF-signals and new positioning algorithms. As there is no single technology neither a sensor nor an RF-signal that is capable to provide positioning solutions under all circumstances (indoors and outdoors), integration of multiple sensors and multiple RF-signals is the only option at present. This approach takes the advantages of each sensor to form an optimal solution. As mentioned above, the performances of most sensors currently adopted for the hybrid position solution are affected by the ambient environments, new sensors such as camera and EMG (Electromyography) sensor, which are not affected by the ambient environment, are now being investigated for this purpose. In addition to new sensors, new RF-signal such as Low Energy (LE) Bluetooth signal will bring new solution to the portfolio of the ubiquitous positioning solutions. New positioning algorithms are needed for fusing the new sensors/RF-signals, for improving the positioning availability, reliability and accuracy especially for GNSS signal challenge environments such as urban canyons.