GUEST EDITORIAL

EMERGING OPPORTUNITIES FOR LOCALIZATION AND TRACKING




NADER MOAYERI   JALAL MAPAR   STEFANIE TOMPKINS   KAVEH PAHLAVAN

GPS has been a phenomenal success. Simply consider as examples its use in car navigation systems or walking around city streets with the help of a smart phone. However, GPS is unavailable inside buildings, in urban canyons, underground, and underwater. Developing complementary location and tracking technologies for these environments would unleash the use of such capabilities in many applications in the military, public safety, and commercial arenas. Within residences and nursing homes, for example, there is an increasing need for indoor geolocation systems to track people with special needs, the elderly, and children to relieve the need for around-the-clock visual monitoring. Other applications include systems to assist the visually impaired, locate instrumentation and other equipment in hospitals, and track specific items in warehouses. In first responder/public safety and military applications, indoor geolocation systems are needed to monitor inmates in prisons, locate miners trapped in mines, and track/guide first responders and soldiers inside buildings. Given the growing interest in sensor networks and radio frequency identification (RFID) technologies, one can also envision wider-ranging applications such as locating unwanted chemical, biological, or radioactive materials using sensor networks, and tracking specific items such as controlled pharmaceuticals in their containers using RFID tags.

Localization solutions may have different levels of complexity depending on application requirements and operational environment. For example, zone-level location accuracy via smart phones might be adequate in a shopping mall to determine a person's location relative to a certain store based on the strengths of the signals received from the mall WiFi network. On the other hand, firefighters entering a burning building cannot rely on availability of localization aids such as RFID tags/readers or a WiFi network in the building. Furthermore, the localization system required for this scenario must have an accuracy range of 1 m — if a rescue mission is to be launched — to 3 m. Also, such a system must work from the high floors of multistory buildings to possibly many levels underground and rely solely on the equipment the firefighters can bring to the scene. Under these circumstances, a hybrid solution employing various types of localization " sensors" and a smart data fusion algorithm to combine the sensor outputs is the most promising approach, but the challenge is to make the system small, robust, reliable, simple to use, and inexpensive. Even more complex would be a system for locating an intruder who breaks into a building. This would be an example of noncooperative localization, because a first responder or even an offender roaming city streets while wearing a radio-equipped ankle bracelet is " cooperating" by wearing equipment that makes it possible to track his/her movements, but an intruder is not. These examples suggest that there is never going to be a silver bullet, that is, a localization and tracking solution suitable for all possible applications.

Recognizing the ever increasing importance and potential of localization and tracking, this special issue is designed to provide a snapshot of the state of the technology in this exciting area of R&D activity. The first article, by Rantakokko *et al.*, is a fairly comprehensive overview of hybrid localization solutions for first responder and military applications. It shows how outputs of various sensors can be fused using an (extended) Kalman filter or a particle filter to arrive at a location solution. The next four articles deal with four different mechanisms that are expected to play important roles in localization and tracking, whether standalone or as part of a hybrid solution. The first of these is a comprehensive review of ultra wideband (UWB) technology for time of arrival (TOA) estimation and ranging by Soganchi *et al.* UWB ranging is very precise when the two ranging nodes are in line of sight (LOS) of each other. However, its non-LOS (NLOS) performance is typically inadequate, as the distances up to which this technique works and its precision depend on how many walls or other obstacles are on the straight line connecting the two nodes. The next article, by Bird and Arden, addresses the use of inertial navigation systems for localization and tracking. RF-only solutions are inadequate for estimating a person's or an object's location with adequate precision in many applications and environments (e.g., in large/complex buildings and mines) unless the structure is adequately instrumented. While the drift problems of inertial measurement units (IMUs) are well known, an IMU might be the only sensor capable of providing useful location information in GPS- and RF-degraded environments. The next article, by Soloviev and Dickman, addresses techniques to extend the operational range of GPS, such as within the periphery of buildings. In general, GPS is going to continue to play an important role in localization and tracking, because it is the only mechanism that provides location information outdoors all over the world. In a sense, GPS closes the loop in providing a location solution everywhere. The article by Ni *et al.* is on the use of RFID for localization purposes. This is an important area, because passive RFID tags are inexpensive and widely available, and could soon be routinely installed in large numbers in new buildings just the way sprinklers now are. The article briefly touches on the need for a reliable RF link to communicate the location information to another entity, such as when an incident command set up outside a building needs to know the locations of firefighters inside. This is an important issue because it applies to IMU-based solutions, and there are still many problems with radio communications inside large structures, mines, tunnels, and so on.

The article by Draganov *et al.* presents the concept of synthetic aperture navigation (SAN). The idea is to exploit real-time knowledge of user motion to synthetically build a large antenna aperture from a single omnidirectional antenna. This would enable the mobile user to not only estimate range to a signal source/anchor node but also estimate its direction. This can potentially reduce the number of anchor nodes needed by the localization system. The last article, by Lowell, addresses military applications of localization, tracking, and targeting. These applications heavily rely on global satellite navigation systems (GNSS), such as GPS, augmented by a variety of sensors not addressed by the earlier articles.

We expect to see a proliferation of localization and tracking solutions and location-based services over the next decade and their routine incorporation in smart mobile devices. While this Special Issue highlights the importance of localization and identifies the ongoing/remaining R&D topics, it would be worth revisiting this area in five years' time to gauge the level of progress and go over remaining challenges.

BIOGRAPHIES

NADER MOAYERI (nader.moayeri@nist.gov) has been with the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, since 1997. His research interests are in wireless communications, wireless sensor networks, and localization and tracking. Prior to NIST, he was with the Imaging Technology Department at Hewlett-Packard Laboratories, Palo Alto, California, and the Department of Electrical and Computer Engineering at Rutgers University, Piscataway, New Jersey. He received a Ph.D. in electrical engineering — systems from the University of Michigan, Ann Arbor in 1986.

JALAL MAPAR (Jalal.Mapar@dhs.gov) is a program manager at the DHS Science and Technology Directorate where he manages a portfolio of programs that includes the Geospatial Location Accountability and Navigation System for Emergency Responders (GLANSER) and Physiological Health Assessment Sensor for Emergency Responders (PHASER) Programs. Prior to joining DHS, he was a division manager in the RDT&E Group at SAIC, McLean, Virginia, focusing on technology development for several R&D agencies including NASA, DARPA, ONR, and DHS. He holds B.S. and M.S. degrees in aerospace engineering from the University of Texas at Austin.

STEFANIE TOMPKINS (Stefanie.Tompkins@darpa.mil) is a program manager for several positioning- and navigation-related programs at the Defense Advanced Research Projects Agency (DARPA). Prior to joining DARPA, she first served in the U.S. Army, then worked in industry, managing a variety of technology development programs and conducting research as a NASA principal investigator. She received a B.A. in geology and geophysics from Princeton University, and her M.Sc. and Ph.D. from Brown University.

KAVEH PAHLAVAN [F] (kavehpahlavan@gmail.com) is a professor of ECE and CS, and director of the Center for Wireless Information Network Studies at Worcester Polytechnic Institute, Massachusetts. His current area of research is localization using signals of opportunity. He has been the Westin Hadden Professor of Electrical and Computer Engineering at WPI, and has been elected as a fellow of the Nokia and the recipient of the first Fulbright-Nokia scholarship.