NUSTL
NATIONAL URBAN SECURITY TECHNOLOGY LABORATORY

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) program to inform emergency responder equipment selection and procurement decisions.

Located within the DHS Science and Technology Directorate, the National Urban Security Technology Laboratory (NUSTL) manages the SAVER program and works with emergency responders to conduct objective operational assessments of commercially available equipment.

SAVER knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List, focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?"

To explore the full library, visit SAVER online at *www.dhs.gov/science-and-technology/saver-documents-library*.

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Science and Technology

INDOOR POSITION AND LOCATION TRACKING IN THREE DIMENSIONS

During an incident, accurate location is critical information. Emergency call centers need the location of victims to dispatch the response, and incident commanders need to know where responders are to coordinate activities and monitor their safety in evolving situations. In urban settings with high-rise and subterranean locations, the vertical or z-axis location is particularly important. Accurate indoor location tracking can save lives, but it presents many challenges. Equipment for emergency responder location tracking falls under the Authorized Equipment List reference number 04AP-02-OAPT, titled "Operations Area Personnel Tracking and Accountability System."

Overview

Outdoors, global navigation satellite systems such as the U.S. Global Positioning System (GPS) are used in a variety of location applications. GPS operates independently of cellular service and Wi-Fi as a constellation of orbiting satellites, each continuously broadcasting their location and the precise time. A GPS receiver calculates its distance from multiple satellites using the elapsed time between signal transmission and receipt, and the signal speed (speed of light), to determine its location on earth. Longitude (x) and latitude (y) coordinates can be correlated to geographic street maps. Unassisted GPS receivers can provide the outdoor x-y location to within a 16-foot radius [1].

Figure 1. Z-coordinate locations in multi-story buildings
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Using GPS is challenging indoors, because satellite signals may be attenuated, scattered, or blocked by building materials or the earth in subterranean structures. While x-y coordinates are of primary use for outdoor street-level locations, the vertical z coordinate is needed to determine a location within multi-story buildings (Figure 1).

Determining a usable value for a GPS receiver's z coordinate has applications in high-rise emergencies for dispatching and tracking responders. However, it is more complicated than x-y positions. Measurements are calculated from the center of the earth, and the local height may be approximated using a smoothed ellipsoidal model for the earth's shape. Geological survey data may also be used to refine z-value determination for the local terrain. Matching the vertical coordinate to a specific floor in high-rise buildings faces the additional complication that floor-level spacing and numbering conventions vary between buildings. For the position information to be usable for navigation indoors, individual building floor plans would be needed to correlate the x, y and z coordinates with interior locations.

Various technology solutions for z-axis determination and indoor positioning are being developed, using alternative reference transmission stations and other types of sensors to augment satellite positioning systems. [2]

Indoor Positioning Technologies

Indoor network systems for responder tracking use anchor nodes (instead of GPS satellites), which have a known position and relay signals for distance determinations. Various transmission frequencies may be used, including Wi-Fi, Bluetooth, and ultra-low frequencies. While nodes may be pre-installed into building infrastructure, in emergency applications responders typically deploy portable transmitting “beacons” when they arrive at an incident site. Connection with incident command may be intermittent due to signal attenuation and scattering.

Inertial systems for responder tracking use accelerometers and gyroscopes to determine velocity or count steps to calculate an expected location relative to an initial known position. Such sensors may be shoe-mounted and are also present in mobile phones. They can be used to estimate an updated position while a person is temporarily out of range of an indoor networked tracking system’s anchor nodes.

Barometers can be used to determine z-axis coordinates because the earth’s atmospheric pressure decreases with altitude. However, changing weather conditions and pressure variations within controlled indoor air environments may cause inaccuracies.

Outdoor networks of stationary, above-ground transmitters may be deployed to augment satellite systems for local metropolitan-area positioning applications. Altitude stations that monitor local environmental conditions, including atmospheric pressure, may be used to correct variations in barometric measurements to reduce uncertainty in their z-axis determinations. [3]

Proximity search-assist devices provide an indication of the relative strength or directionality of transmitted signals rather than location coordinates. Handheld transceivers using this technology are designed to aid in finding a firefighter distress signal. Signal scattering in building interiors may be a limitation in situations where the strongest transmission path may differ from the most direct rescue route.

Advances in smartphone apps and new requirements for 911 calls may help address z-axis challenges.

Phone Applications

Smartphone capabilities: Indoor-outdoor location capabilities that combine several of the techniques previously described have been developed for smartphones. The location services setting on the phone, when enabled, may use GPS, smartphone-integrated barometers (most smartphones contain barometric sensors [4]), anonymous crowdsourced data, including cell tower locations and Wi-Fi and Bluetooth signals to calculate a phone’s location. [5]

Emergency 911 calls: The Federal Communications Commission (FCC) requires that mobile phone providers transmit the horizontal and vertical location coordinates with 911 calls. The FCC mandated that z-axis-enabled mobile phones have vertical location accuracy of ± 3 meters for 80% of indoor wireless 911 calls in place for the top fifty cellular market areas nationwide by April 3, 2023. [6] Also, the FCC requires the z coordinate be delivered as the height above ellipsoid and provide building floor information where available. The capability for public safety call centers to convert mobile phone coordinates to dispatchable locations would help responders get to where they are needed and may improve awareness of onsite threats.

Applicable Standard

ISO/IEC 18305:2016 identifies performance metrics and test and evaluation scenarios for indoor localization and tracking systems. [7]

References

[1] National Institute of Standards and Technology, "How Do You Measure Your Location Using GPS," 4/4/22.

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[3] NextNav, "NextNav TerraPoiNT," 2023

[4] W. Falcon and H. Schulzrinne, "Predicting Floor Level for 911 Calls with Neural Networks and Smartphone Sensor Data," in *International Conference on Learning Representations*, 2018.

[5] N. Moayeri and C. S. L. Li, "Indoor Location Accuracy of Major Smartphone Location Apps," in *IEEE Wireless Communications and Networking Conference*, Marrakesh, Morocco, 2019.

[6] Federal Communications Commission, "Wireless E911 Location Accuracy Requirements,"01/16/20.

[7] "ISO/IEC 18305:2016 Information technology - Real time locating systems," International Organization for Standardization, 2016.