Improving Location Accuracy Using Cooperative Positioning

By

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Presentation Outline

• Limitations of GNSS

• Conventional Positioning Systems

• Cooperative Positioning System
  – Ranging Techniques
  – Position Estimation Algorithms
  – Terrestrial Communication

• Conclusion
Limitations of GNSS

• The performance of a global navigation satellite system (GNSS) receiver is known to be very good in open sky conditions.

• The augmentation such as DGPS, RTK, A-GPS, SBAS and GBAS may be used to improve the receiver performance.
Limitations of GNSS

• Conventional Positioning Systems
Limitations of GNSS

- These techniques commonly have **stringent requirements** on the received GPS signal quality, e.g., low multipath errors and the visibility of multiple satellites, which are not viable in **dense urban** areas.

- In difficult situations, like natural/urban canyons, wooded areas, inside buildings, at high altitude, or in the presence of electromagnetic interference GNSS receiver performance may strongly attenuated.
Cooperative Positioning System

- In cooperative positioning, GNSS users or receivers exchange their GNSS data and information about their position with their neighbors.
Cooperative Positioning System

• Each GNSS user is equipped with a **GNSS receiver** and a **communication system** for transmitting and receiving of GNSS data and positioning information.

• Type of GNSS sharing data may include
  – Information about number of visible satellites, their carrier-to-noise ratio (C/N), Doppler, receiver observable, messages provided by the GNSS and augmentation systems, **raw data**, **pseudoranges**, computed altitude, **computed position**.
Cooperative Positioning System

- Functioning of CP system

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Cooperative Positioning System

• In order to implement a cooperative positioning algorithm, every GNSS user has to execute three different tasks namely

  – Ranging
  – Positioning and
  – Broadcasting aided values.
Ranging Techniques

- Radio-based ranging can be used in CP for distance estimation between cooperative users.

- Radio range based CP includes
  - Time of Arrival (TOA)
  - Time Difference of Arrival (TDOA)

- Demerits: Time-based methods are more complex and expensive due to stringent synchronization requirement.
Ranging Techniques

- Two Way Ranging (TWR) or (Round Trip Time) RTT

- Experimental results show that, with two stationary nodes, the accuracy of 1 to 9 m was achieved.

- Disadvantage of RTT based ranging is the computational complexity required for achieving better ranging resolutions through averaging the estimates.
Ranging Techniques

• RSS-Based Ranging

The node measures the power of a signal transmitted by a neighbor. If we know the received power and environmental parameters, the distance can be estimated.

\[ d_{ij} = \left( \frac{P_{ij}}{P_0} \right)^{-\frac{1}{n}} d_0 \]

The connection between the transmitted and the received power strongly depends on the environment.
Estimation Algorithms

• Estimation algorithms can be used to integrate information from satellites and neighboring peers and solve the hybrid set of equations. These include

  – Least Squares (LS),
  – Kalman Filter (KF)
Estimation Algorithms

• Least Squares (LS)

Least Squares (LS) is one of the most widely used deterministic techniques for solving the Position Time problem. Given the measurements, the coordinate values are chosen to minimize a given error function.

• The main drawback is that it does not consider the measurement statistical model.
Estimation Algorithms

• Kalman filter

• This algorithm takes into account the statistical modeling of state and measurements. The extended Kalman filter (EKF), which linearizes observed pseudoranges and terrestrial ranges is widely employed for tracking in GNSS receivers.
Estimation Algorithms

- Sum Product Algorithm over a Wireless Sensor Network (SPAWN)

- SPAWN can be implemented in a fully distributed way through local exchange of messages between pairs of neighboring nodes. Because it relies on a probabilistic, Bayesian approach, all quantities of interest (e.g., position and bias estimates, and terrestrial range/pseudorange measurements) are modeled as probability distribution functions.

- This makes the approach a truly distributed algorithm which is highly suitable for CP. SPAWN provides excellent performance even in challenging conditions, including large-scale networks, mobile nodes, low degrees of satellite visibility, and multi-hop peer-to-peer communication.
Terrestrial Communication System

• The communication system used for message exchanging may be completely independent from the system used to perform terrestrial ranging or it may exploit the same signals used for ranging.

• UWB devices are also effective in non-line-of-sight (NLOS) conditions, propagating through two (sometimes even three) walls. If the system is deployed in an deeply indoor environment with many thick walls with lots of metal/reflectors, the performance of the UWB system may deteriorate.

• UWB modules are available, and results from UWB ranging based on real measurements show that this technique has very good potential.
Conclusion

• We have present the concept of cooperative positioning specifically applicable for GNSS user in light and deep indoor environments.

• It has been shown that for positioning estimation each cooperative GNSS user can exploit WSN algorithms like UKF, SPWSN which can be applicable in cooperative positioning system.

• A prototype or real time testing of hardware is not exist in the literature. For the practical of CP, hardware level validation experiment is needed in the future.
Thank you