Mapping and Exploitation of Navigation Signals of Opportunity

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MOTIVATION

Global navigation satellite system (GNSS) is at the heart of autonomous vehicle navigation systems. However, GNSS signals are unreliable due to:

- Severe attenuation in deep urban canyons
- Intentional and/or unintentional jamming
- Spoofing

APPROACH: CoPNav

Collaborative opportunistic navigation aims to exploit signals of opportunity (SOPs) in the environment.

CHALLENGES

- Unavailability of most SOP emitters’ states (position and clock)
- Less stable clocks than GNSS satellite vehicles
- Unavailability of receiver architectures for navigation observables extraction

ADVANTAGES

- Available from varying geometric configurations
- Abundant and free to use
- Higher received power compared to GNSS signals

OPTIMAL RECEIVER PLACEMENT

Consider a planar environment comprising $M$ unknown SOPs and $N$ arbitrarily placed receivers with knowledge about their own states. The receivers draw pseudorange observations given by

$$ m z_n = \| r_n - r_{\text{true}} \| + c \cdot (\delta t_n - \delta t_{\text{true}}) + \mu n, $$

where $z_n$ represents the pseudorange observation, $r_n$ and $r_{\text{true}}$ are the receiver and true positions, respectively, $c$ is the speed of light, $\delta t_n$ and $\delta t_{\text{true}}$ are the clock errors, and $\mu n$ is the measurement noise.

1. **Accuracy Improvement: GPS+SOPs**

   (a) minimize
   $$ r_{N+1} \quad \sqrt{\text{tr} \left( H^T:H(r_{N+1}) \right)^{-1} } $$
   (b) maximize
   $$ \det \left( H^T:H(r_{N+1}) \right) $$
   (c) maximize
   $$ \sum_{m=1}^M \log \left| A \left( m \phi_{N+1} \right) \right| $$

2. **Receiver localization improvement**

   Unavailability of SOP emitters’ states
   - Position and clock

3. **Signal Landscape**

   Available from varying geometric configurations

4. **Vertical error reduction**

   Higher received power compared to GNSS signals

EXPLOITING SOPs

1. Accuracy Improvement: GPS+SOPs

   - GPS only
   - GPS+3 SOPs

2. UAV Simulation Results

   - GPS only
   - GPS+3 SOPs
   - True trajectory

EXPERIMENTAL DEMO

1. Collaborative Mapping of SOP

   Receiver trajectories

   - Initial uncertainty
   - Final uncertainty

2. Receiver localization improvement

   Mapped SOP locations
   - Estimated receiver location

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REFERENCES