TrackIO: Tracking First Responders Inside-Out

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Firefighter trapped in Chicago elevator during rescue

When rescuing elevator stalled, other firefighters considered breaking through wall to enter elevator shaft
Tracking emergency responders in real-time is crucial.

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Tracking Personnel Indoors is Challenging

- No access to GPS indoors.
- Inertial sensors (IMUs) can drift drastically with time ultimately losing track of the position.
- No access to indoor infrastructure. Positioning solutions involving Wi-Fi or BLE (Bluetooth) beacons are impractical in such situations.
- Tracking needs to be real-time.
Ranging is fundamental. Infer the distance between two wireless devices.

However, ranging from a single vantage point is insufficient to resolve the location.
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However, ranging from a single vantage point is insufficient to resolve the location.

At least, 3 probing locations are required to resolve location in 2D. 4 in case of 3D. (multilateration)
Ultra-Wideband (UWB) technology offers ranging accuracy up to 10 centimeters.

UAVs or drones are attractive options for realizing such flexibility in 3D space.
The TrackIO Solution

Indoor UWB Beacon
The TrackIO Solution

UWB Two-Way Ranging: Precise to 10 centimeters
Towards TrackIO Solution

UAV collects many ranges over time

UAV trajectory forms a synthetic aperture

Works fine for static nodes
UAV collects many ranges over time.

UAV trajectory forms a synthetic aperture.

Tackling Turns

Limited Reachability

Mobile Node
Design Challenges

UAV collects many ranges over time

UAV trajectory forms a synthetic aperture

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Mobile Node
Node Mobility: Solve for Velocity

\[ R_i = \sqrt{(Cx_i - x_i)^2 + (Cy_i - y_i)^2 + (Cz_i - z_i)^2} \]

Drone Locations

\[ x_i = x_{i-1} + V_x \cdot \Delta T_i = x_1 + V_x \sum_{j=1}^{i} \Delta T_j \]

\[ y_i = y_{i-1} + V_y \cdot \Delta T_i = y_1 + V_y \sum_{j=1}^{i} \Delta T_j \]

\[ \text{argmin}_{x_1, x_2, V_x, V_y} f = \sum_{i=1}^{n} \left( (Cx_i - x_i)^2 + (Cy_i - y_i)^2 + (Cz_i - z_i)^2 - R_i^2 \right)^2 \]
Tracking Velocity Vector Improves Performance

![Graph showing localization error for different speeds with Naive Multilateration and TrackIO]
Design Challenges

UAV collects many ranges over time

UAV trajectory forms a synthetic aperture

Tackling Turns

Mobile Node

Limited Reachability
Tackling Turns: Adaptive Aperture

Smaller Aperture ➔ Less Historic Data
❌ Poor Localization Accuracy
✔ Adapts Quickly to Velocity Changes

Larger Aperture ➔ More Historic Data
✔ Good Localization Accuracy
❌ Adapts Slowly to Velocity Changes
Tackling Turns: Adaptive Aperture

Uniform Velocity $\rightarrow$ Larger Aperture

Non-Uniform Velocity $\rightarrow$ Restart Aperture

Change in velocity is estimated by sudden changes in the solver’s residual
Reliability of Turn Detection

High solver residuals \(\rightarrow\) P2P Measurements

Turn Detected

Low solver residuals

Low solver residuals

Localization Error (m)

Time (seconds)

Residuals (no units)
Limited Reachability: Multihop Ranging
Limited Reachability: Multihop Ranging

Hop-1

Hop-2
TrackIO Performance

Covers about 1300 sq. meters
TrackIO Performance

- CDF vs Localization Error (m)
  - Static
  - LINE
  - TRIANGLE
  - RECT

- Localization Error (m) vs Hop for Static Hop-1 and Mobile Hop-1
  - Hop-1 Nodes
  - Static Hop-2 Nodes
  - Mobile Hop-2 Nodes
TrackIO UAV

[Diagram of a drone with labels for RPi, GPS, and UWB Node]
Salient Points

• TrackIO offers a localization solution without the dependence of pre-deployed indoor infrastructure.

• UWB technology provides accurate ranging, which combined with the flexible UAV trajectory offers localization accuracy as good as 1 – 2 meters.

• TrackIO’s multi-hop ranging protocol helps deeper penetrability indoors.

• Various fire departments and government entities has already shown reasonable interest in our tracking technology for subsequent commercialization.
Please visit the link for a demo.
http://www.nec-labs.com/trackio

Thank You

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