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Technical Challenges in Indoor Localization of First Responders

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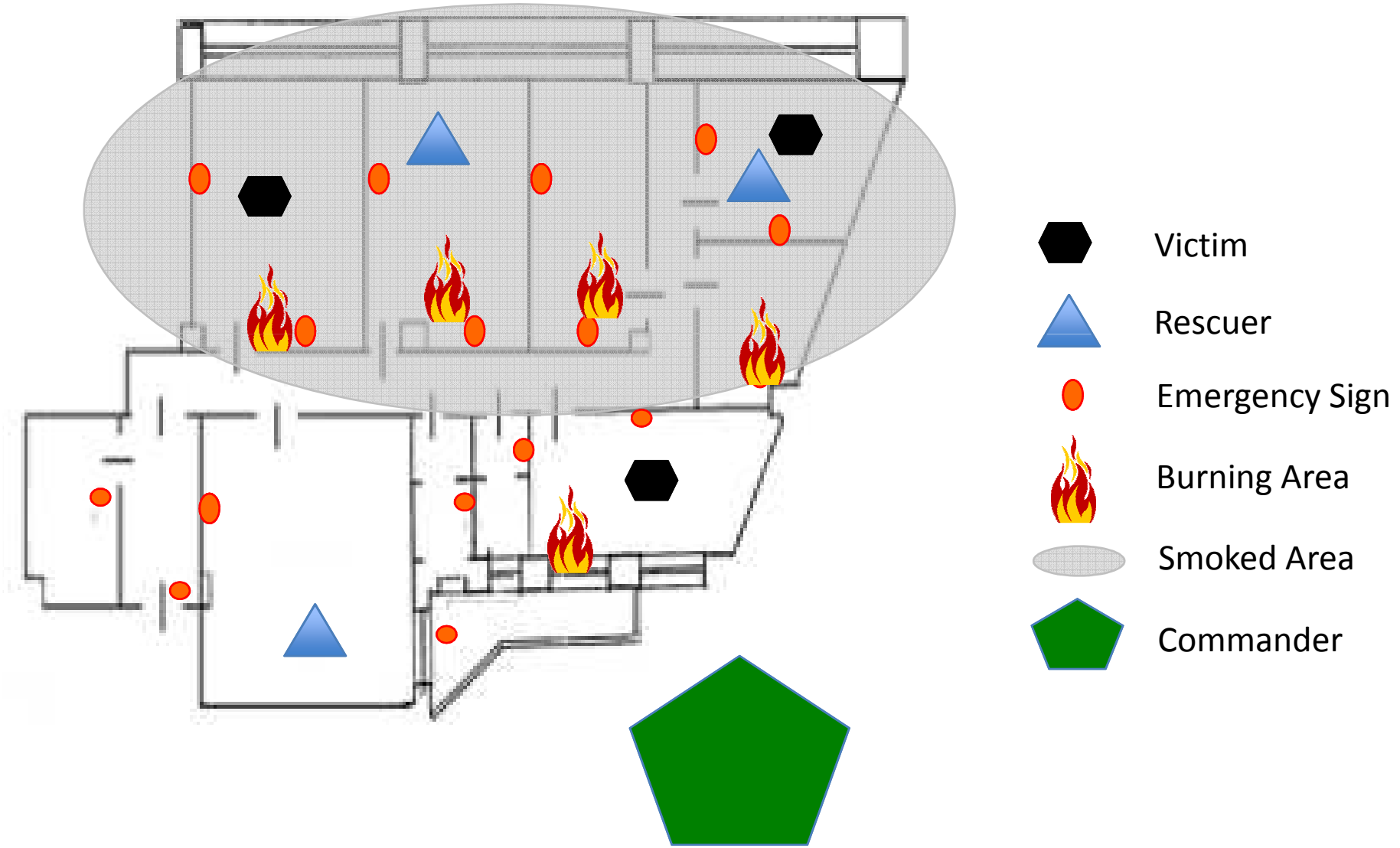
Overview

- Motivations
- Localization for FR
- Practices
- High Tech localization systems
- Review of the localization systems
- Conclusions

Indoor Emergency Scenario



Localization of FRs

- Being aware of rescue team location
  - Increases safety
  - Decreases mission time
  - Improves team coordination
  - Reduces chances of disorentation

- Ensure that the Incident Commander receives pertinent information from occupants on scene and information relayed to crews during sizeup;
- Conduct research into refining existing and developing new technology to track the movement of fire fighters inside structures.

Rescue Localization

- Localization and navigation practices
  - Low tech equipment
  - Training
- Infrastructure based localization
  - Wireless sensor networks
- High-tech systems
  - Wearable sensors

NIOSH recommendations

1. Using of low tech equipment exploiting existing landmark
2. Improving team-commander communication
3. Developing new technology for localization

Practices

- Hose following
- Lifelines
- Flashlight
- Chalk mark
- Personal Alert Safety System

Infrastructure based localization

- Pre-deployed infrastructure
- Deployable sensor networks
- Density
- Measurements
- Quality of information

Localization for Sensor Networks

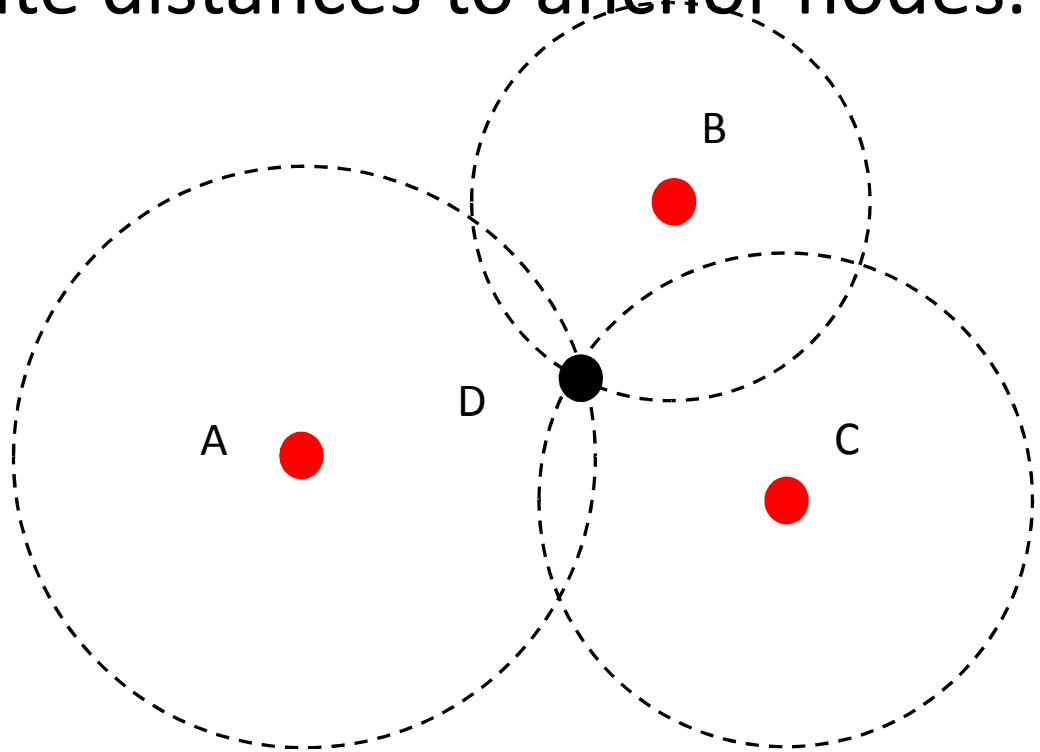
- Output: nodes' location
  - Global location, e.g., what GPS gives
  - Relative location
- Input:
  - Connectivity, hop count (under Unit Disk Graph model)
    - Nodes with k hops away are within Euclidean distance k
    - Nodes without a link must be at least distance 1 away
  - Distance measurement of an incoming link
  - Angle measurement of an incoming link
  - Combinations of the above

Localization algorithms for a network

- **Anchor-based**
  - Some nodes know their locations, either by a GPS or as pre-specified
- **Anchor-free**
  - Relative location only
  - A harder problem, need to solve the global structure: nowhere to start.
- **Range-based**
  - Use range information (distance estimation).
- **Range-free**
  - No distance estimation, use connectivity information such as hop count.

Triangulation, trilateration

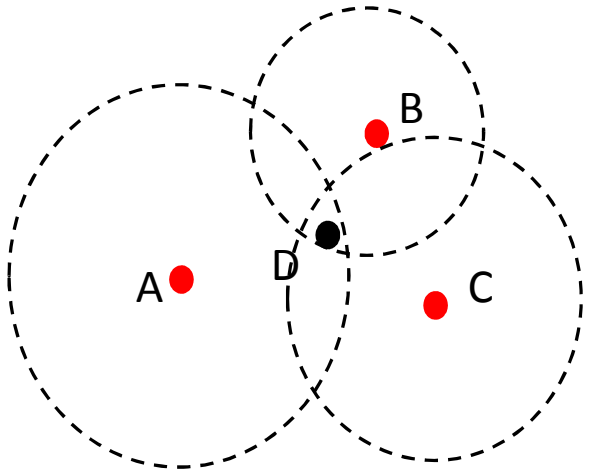
- Anchors advertise their coordinates & transmit a reference signal
- Other nodes use the reference signal to estimate distances to anchor nodes.



Triangulation, trilateration

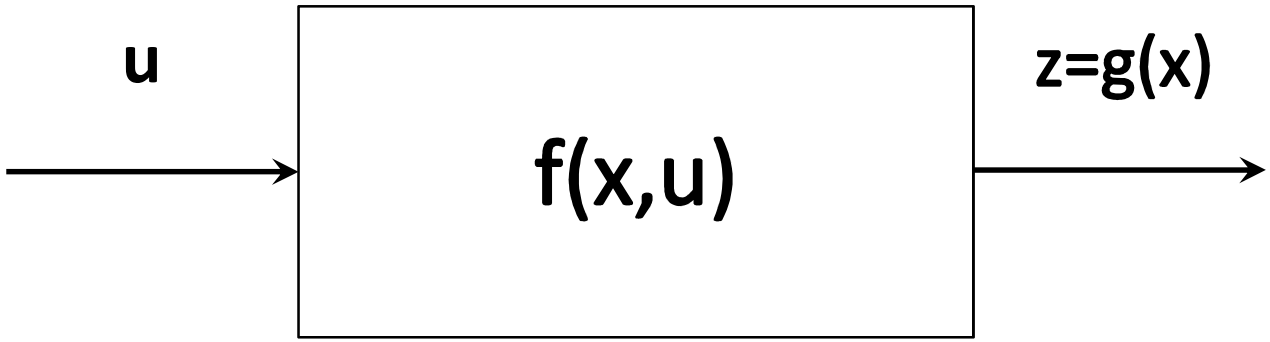
- Problems:
  - Distance measurements are noisy!
  - What happens if there are more than 3 anchors?
- Solutions:
  - Set up an optimization problem: minimize the mean square error
  - Set up a data fusion algorithm

GPS APPROACH!!



Beyond GPS: robotic approach

- The dynamic of the mobile node is not used
  - TomTom prediction under tunnel
- An observer can be set up to estimate the node location



Predictor-Corrector filter

- The dynamics of the system is used to form a rough prediction on the state trajectory
  - TomTom: vehicle heading and velocity + map of the environment
- The measurements are used to refine the initial guess
  - TomTom: GPS signals (when available)

    - **RESULT**: we know (roughly) our position even if GPS signals are not available!!!

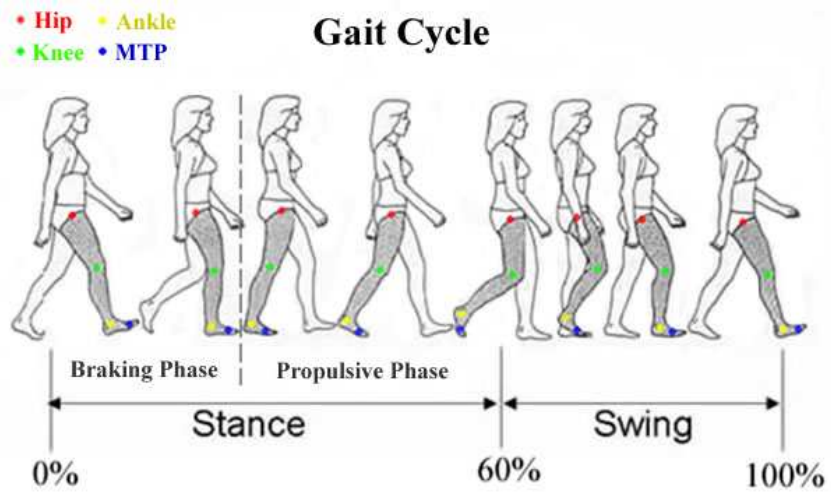
Pedestrian kinematic model

$$\mathbf{x}_k = \mathbf{x}_{k-1} + \rho_k \begin{bmatrix} cos(u_{k-1}) \\ sin(u_{k-1}) \end{bmatrix}$$

- Problems:
  - How to find the displacement??
  - How to find the heading??

Displacemement

$$\rho_k = \text{h}\sqrt[4]{a_{max} - a_{min}}$$



- Open problems
  - How to calculate h??
  - How to indentify a_min & a_max??

  - **How to find the heading??**

Heading

- Quaternion
  - The heading is computed using tri-axial accelerometer + tri-axial gyros
    - Bias + scale
- Magnetometer
  - The heading is the output of the sensor
    - External magnetic disturbance

Heading

- Fusion algorithm for Heading
  - Extended Kalman Filter
    - PREDICTION
      - Compute heading by exploiting quaternion from gyro data
    - CORRECTION
      - Compute heading by exploiting quaternion from acc data
      - Compute heading using magnetometer

Pathfinder

- Handheld tracker
- Beacons

- Ultrasound
  - Smoke, heat, and audible sounds from the fire don't interfere with the ultrasonic waves

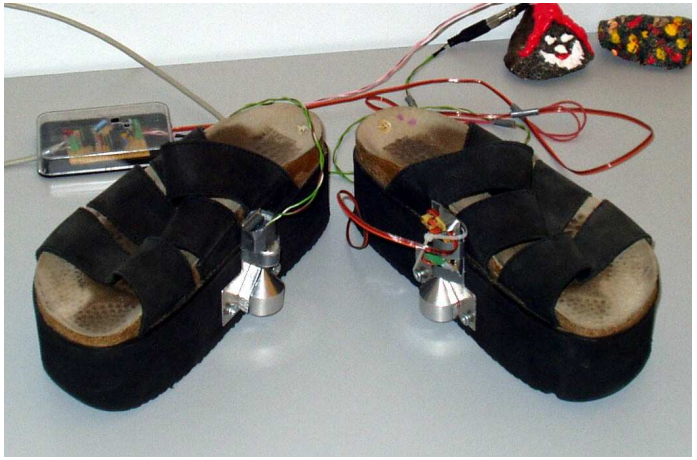
FIRE Project

- SmokeNet
- FireEye (HDM)
- Fingerprinting

PeLoTe Project

- PDR

- Map based filtering
  - laser

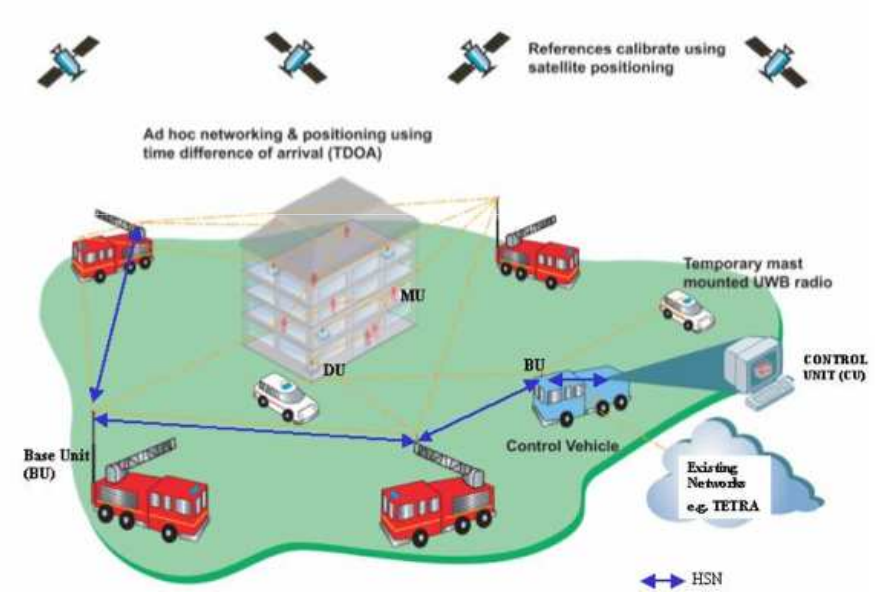


LIFEnet WearIT@Work project

- Ultrasound deployable network
- Head Mounted Display
- PDR

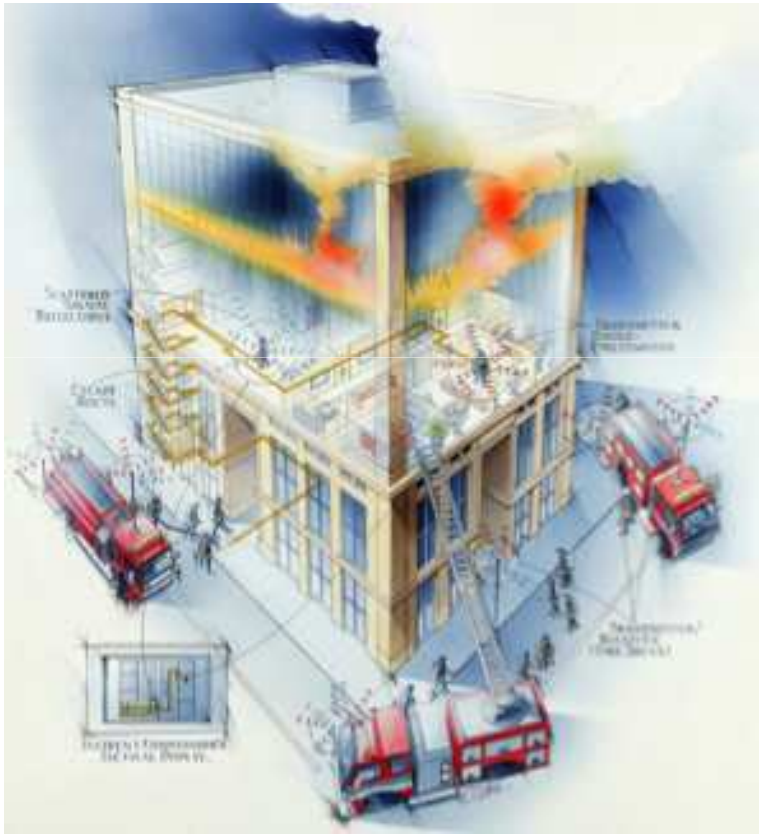
EUROPCOM Project

- Base Units outside the emergency area
- Control Unit outside the emergency area
- Mobile units carried by FR
- Dropped units to guarantee communication



WPI Precise Personnel Location System

- PDR
- UWB multi carrier signals
- Deployed outside the emergency area



LIAISON Project

- PDR
  - Fuzzy rules to identify gait
- RFID
  - Deployable tags

RESCUE Project

- PDR
- GNSS
  - When available!!

Conclusion

- There is no off-the-shelf solution for FR localizations
- Model for dynamics of moving objects
- Pedestrian dead reckoning is affected by drift
  - Gait cycle identification
  - Heading estimation

- External network integration
- No standard protocols for indoor navigation are available

Open problems

- How to calculate a??
  - Acc data can be transformed from their representation in a reference frame fixed on the rescuer in a representation in a reference frame fixed on the ground
- How to identify a_min & a_max??
  - It depends on data ☹