SafeT-Net: Situational Awareness For Emergencies Through Network-Enabled Technologies

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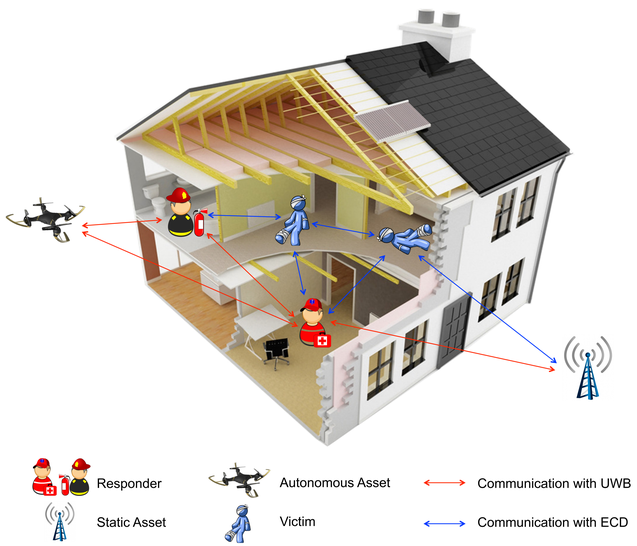
Project Overview

Project Objective: SafeT-Net aims to raise situational awareness in first responder operations and to accelerate research, development, production, as well as testing of localization and mapping technologies for public safety applications. The main focus lies in providing accurate location and environmental information for firefighters or policemen that enter a building in emergency situations.

Challenges:
- Optical localization techniques are unsuitable since fire, smoke, and obstacles restrict the visibility.
- Localization using radio links is challenged indoors by the multiple propagation paths and the absence of line-of-sight propagation.
- Floor plans may be outdated or incomplete due to building damage.
- Deployment of assets is limited because of the inaccessibility of certain areas.

Project Impact:
- Shorter response times and a more efficient use of responder resources, thereby limiting negative effects and minimize casualties in public safety emergencies.
- Technology transition of localization and communication equipment for first responder operations.

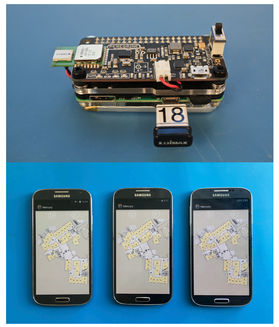
The Paradigm of Network-Enabled Technologies
- The network consists of responders, assets, and victims.
- Utilize different radio technologies such as ultra-wideband (UWB) communication and multicarrier techniques.
- Cooperation among nodes increases localization reliability and accuracy.
- Establish management and control strategies for asset deployment as well as efficient allocation of communication resources.



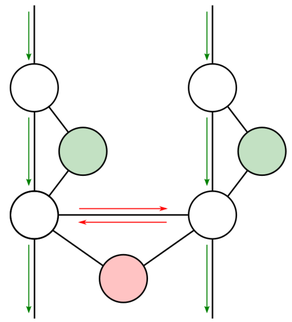
Robust Localization

Research Objective: Establish algorithms to localize responders, their assets, and victims accurately and timely in a robust manner.

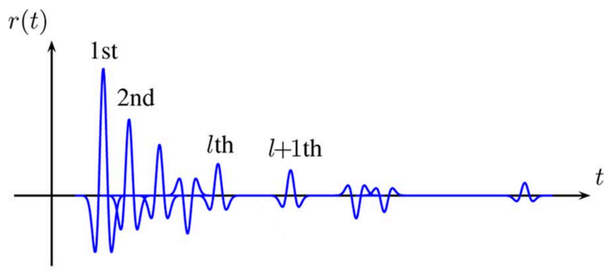
Methodologies:
- Exploiting measurements obtained from devices with different hardware capability. Responder-to-responder and responder-to-asset ranging will be obtained via inexpensive and lightweight devices using UWB technology; responder–to-victim and asset-to-victim ranging will be obtained via end-user communication devices (ECDs).
- Developing Bayesian inference algorithms based on belief propagation (BP) and using the concept of sigma points. BP enables distributed and scalable cooperative localization. A sigma point implementation of BP algorithms facilitates efficient information fusion on resource-limited devices.
- Establishing simultaneous localization and mapping (SLAM) algorithms to infer map information. The SLAM algorithms extract environmental information based on the multipath components contained in received UWB signals.



Measurements from different types of devices



Belief propagation in cooperative networks



Resolve multipath components using UWB

Research Tasks:
- Establish cooperative localization techniques for ECDs.
- Design data fusion techniques for resource-limited devices.
- Develop SLAM algorithms to refine indoor floor plan information.

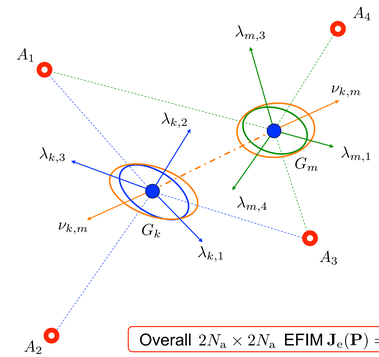
Asset Management and Deployment

Research Objective: Design context-aware optimization and control strategies for efficient use of localization assets.

Methodologies:
- Adopt measures of information such as *negative posterior entropy* or *mutual information* to develop strategies to maximize the available position information under resource limitations.
- Develop holistic control strategies to jointly determine the positions of the mobile assets as well as the transmission bandwidth and power for coordinated operation of autonomous assets (e.g., unmanned aerial vehicles).

Research Tasks:
- Develop asset management algorithms that exploit contextual information and enable resource-efficient operations.
- Establish techniques for asset deployment that allow accurate responder and victim localization with a limited number of static assets.
- Design strategies for the repositioning of static assets, and algorithms for controlling movement and allocating resources of autonomous assets.

Cooperative Localization Interpretation [IEEE Trans. Inf. Theory, Oct. 2010]



2×2

$$\mathbf{J}_{\mathrm{e}}^{\mathrm{A}}(\mathbf{p}_k) = \sum_{j \in \mathcal{N}_{\mathrm{b}}} \lambda_{kj} \cdot \mathbf{J}_{\mathrm{r}}(\phi_{k,j})$$

Range information

Overall $2N_{\mathrm{a}} \times 2N_{\mathrm{a}}$ EFIM $\mathbf{J}_{\mathrm{e}}(\mathbf{P}) = \mathbf{J}_{\mathrm{e}}^{\mathrm{A}} + \mathbf{J}_{\mathrm{e}}^{\mathrm{C}}$

Ellipses denote localization information

Timeline and Milestones

Tasks	Year 1	Year 2	Year 3
Robust Localization			
Multipath-aided localization			
ECD cooperative localization			
Lightweight SLAM algorithm			
Asset Management and Deployment			
Optimal asset management			
Asset deployment			
Control strategies for mobile assets			
Proof-of-Concept			
UWB cooperative localization			
ECD cooperative localization			
Indoor SLAM			

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Representative Public Safety Video Dataset

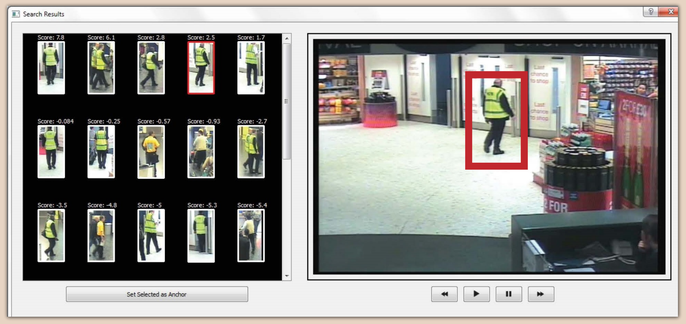
Approach – Accelerate Video Analytics R&D

Example Enabled Video Analytics Capabilities

Content Search

Person Attribute Search

Find males with yellow shirt and black pants

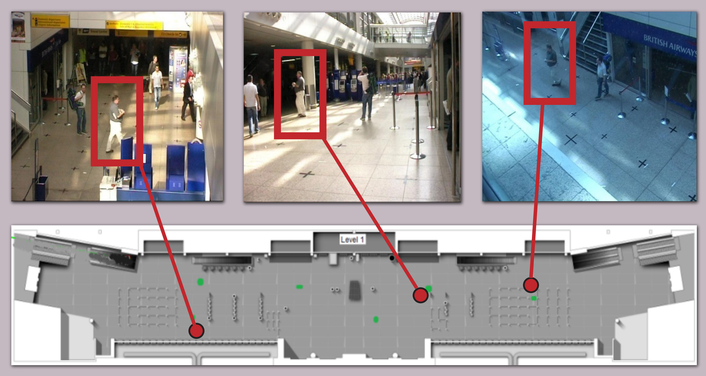


Vehicle Attribute Search

Find white sports utility vehicles

Rapid Activity Review

Multi-Camera Path Reconstruction

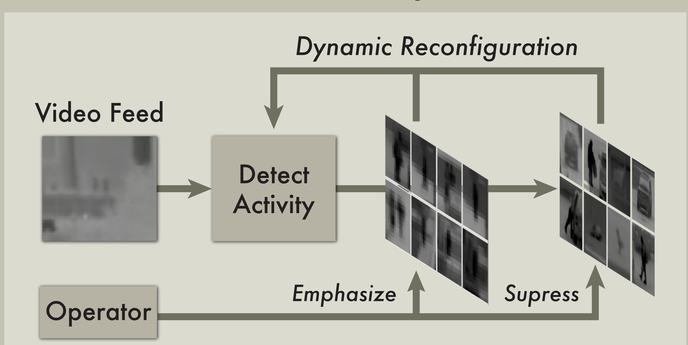


Video Summarization

Original Video *Summary Video*

Activity Detection

Customizable Activity Detection



Long-Range Activity Detection

Low- Pixel-Count Pedestrian Activity

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