Full-Scale Airport Security Checkpoint Simulation

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Awareness and Localization of Explosives-Related Threats

A Department of Homeland Security Center of Excellence

Goals

Overall, this project aims to design a visual tracking system for a 2500 ft^2 black box studio at RPI's new Experimental Media and Performing Arts Center, enabling real-time multi-person tracking for a wide range of research applications.

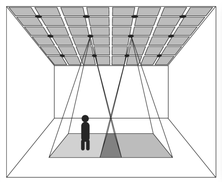
The first goal of the project is to provide the user with real-time estimates of the (x,y) floor positions of all the people in the studio. Subsequent research goals include highly efficient intrinsic and extrinsic calibration of the camera array, automatic multi-person tracking algorithms under complex conditions such as dimly lit or crowded scenes, and interactions with other sensors and actuators such as wall-mounted pan-tilt-zoom cameras, projectors, lights and audio recorders. We expect the system to became a valuable research testbed and infrastructure addition to EMPAC that will improve the utility of the studio space and promote interaction between scientists, engineers, and artists.

Research Problems

A wide variety of homeland-security-related research problems can be undertaken with the camera array, such as:

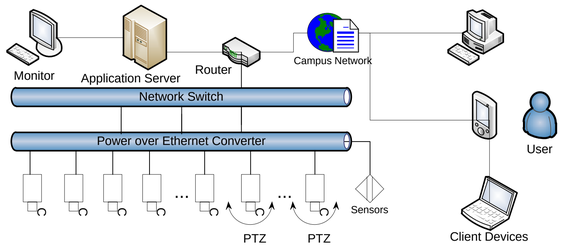
- Flow analysis in crowded scenes
- Change and anomaly detection
- Large-scale environment mock-ups
- Automatic object-to-person association

Camera Array



Side view of Studio 2

Fixed and PTZ Cameras

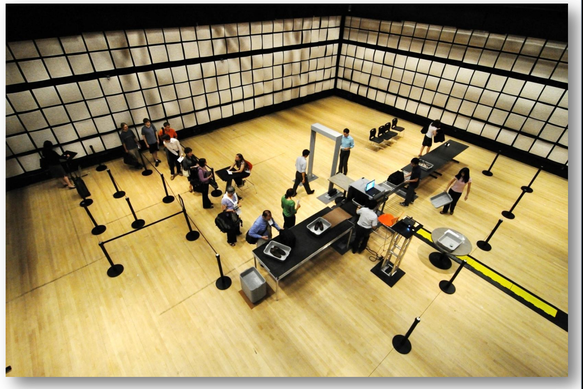


Network diagram of the system

13 fixed and a dome PTZ cameras are mounted at the interstices of the catwalk to cover the entire floor. 5 PTZ cameras are mounted on the wall panning regularly. Each camera delivers images at about 10 Hz which is sufficient for real-time tracking. An application server open to the campus network is managing the network and controlling the cameras.

Airport Security Checkpoint Simulation

We have set up an airport security checkpoint simulation environment with the tracking system, aiming to investigate research problems associated with security, crowd scene analysis, and associating people with bags.

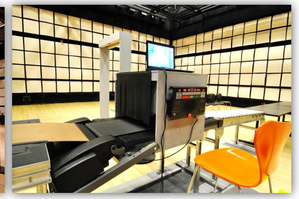


Simulation environment

Several groups of volunteers participated in the simulation as passengers. They were asked to go through the checkpoint with baggage as they do at real airport checkpoints. Each round of simulation was monitored and recorded by the camera network. More than 10 hours and 300GB of multicamera video clips were collected during the one month simulation.

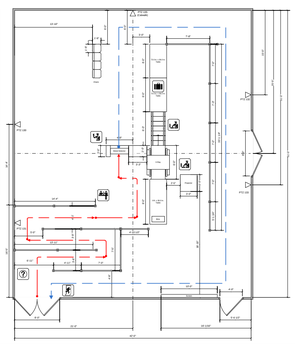
The goal of the research includes detecting and monitoring passenger behavior, associating baggage with passengers, and detecting abnormal issues.

Entrance of the checkpoint



Simulated X-Ray machine

Metal detector and ID Checking

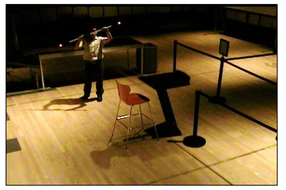


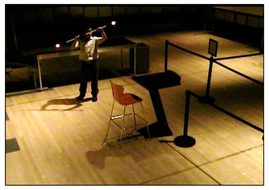
Floor plan of the security check point. The red line shows the entry path while the blue line shows the exit path.

System Calibration

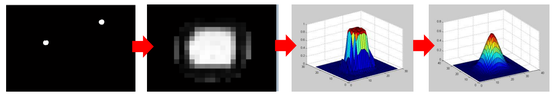
Before mounting the cameras in the grid, we estimated their intrinsic parameters (i.e., focal length, principal point, skew, and lens distortion) using a pattern on an LCD monitor. After the cameras are mounted, we need to accurately calibrate the extrinsic parameters w.r.t. the world coordinates on the floor of the studio. A scale bar with two active-lighting control points on the endpoints was used as the calibration target in order to provide corresponding points and scale for solving the extrinsic parameters for multiple cameras. The calibration consist of the following steps:

- Calibrate 6 PTZ cameras simultaneously.
- Calibrate fixed cameras in groups with respect to PTZ cameras (Adjusting pan and tilt parameters).
- Unify calibration results based on different references.

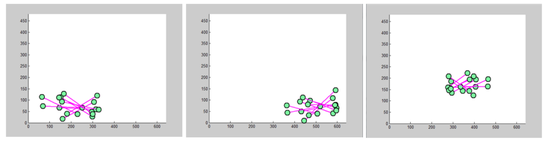




Calibration image with scale bar LEDs on and off.

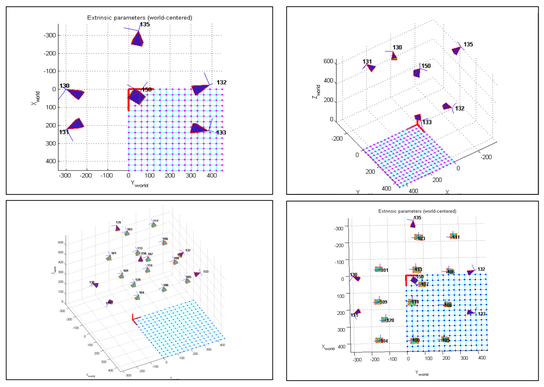


Control Points Extraction



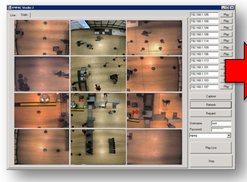
Extracted corresponding control points

The reconstructed length of scale bar (1.18m) was used to evaluate the calibration precision, the relative error of which ranged from 0.1% to 0.3%.

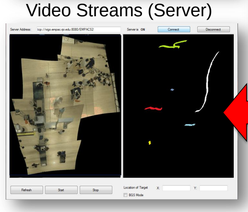


System Calibration Result

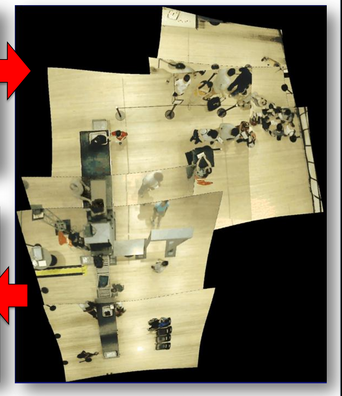
Multi-Person Tracking



Video Streams (Server)

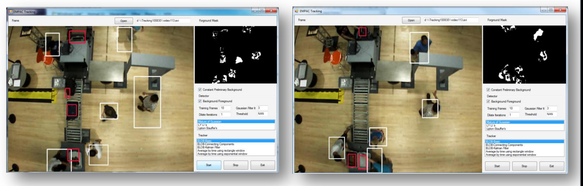


Tracking Result (Client)



Stitched image

A position tracking application is developed to provide the user with real-time estimates of the floor positions of all the people in Studio 2. First we stitched the images from all the cameras using the calibration result. A foreground detector based on Mixture of Gaussian method is used for the tracker. However, multiple people with baggage in crowds is a challenging problem. Additional constraints (head & shoulder detection, previous speed and position of each tracked object, etc.) are added to improve the result of tracking.



Tracking application for airport security checkpoint

We are developing the vision algorithms for airport security checkpoint simulation which can automatically differentiate passengers and baggage, and associate baggage to passengers. As can be seen on the screenshots of the user interface, bags are detected as red rectangles while passengers are detected as white rectangles. Extrinsic calibration results will be used to get more robust and precise tracking results.

In addition to the tracking results, new sensors, actuators, and cameras can be added to the system to provide reaction and feedback that can greatly extend the capabilities and usefulness of the system.

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