MICROSCOPIC MODELING OF CROWDS INVOLVING INDIVIDUALS WITH PHYSICAL DISABILITY: EXPLORING SOCIAL FORCE INTERACTION

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Outline

Crowd Emergencies and Evacuations

- This year 12 children killed during a crowd evacuation due to an earthquake in Afghanistan [1].
- This year crowd crush and stampede attributed to +2000 deaths in the Hajj Pilgrimage [2].
- 61 people killed in a crowd during a 2013 New Years celebration on the Ivory coast [3].
- Of a review over 30 years of mass casualties, 162 events attributed to crowd environments [4].
- University of Kansas (2007), only 21 % of emergency management had plans for Individuals with Disabilities in a Evacuation [5].

Disability and Evacuation

- White House on the Hurricane Katrina, 75 % of fatalities elderly or disabled individuals [6]
- During the World Trade Center plane attacks and estimated 23% had some disabling condition for evacuation [7].
- Court records Hurricane Sandy, emergency management: “no specific policies in place for disabled individuals” [8].
- The World Health Organization (WHO), 15 percent of earth’s population disabled: one billion people [9].
- In some populations those individuals with disabilities can make up nearly 25% of the population [10].

Individuals with Disabilities Evacuations Studies

- Recent studies show evacuation models with individuals with disabilities fall short in the varieties and social interaction [11-13].
- Of a review of 25 studies, none looked at evacuation policies involving the disabled [14].
    - Only one focused on changing the speed of an individual with disability, but does not match empirical results.
    - None focused on the variety of differences in individuals with physical disabilities
        - Groups involving the visually impaired, those using motorized, non-motorized wheelchairs, and roller walkers, hearing impaired, and those with other stamina impairments.

Individuals with Disabilities Evacuations Studies

- To improve overall crowd evacuation, including those with disabilities, the varying differences between these mobility groups must be characterized [13-15].
- Some initial work has been done to model the varying differences of individuals with disabilities [12,14, 16, 19], however without knowledge of actual interactions inside a crowd.
- Initial research should study crowd interactions within built environments that are Americans with Disabilities Act Accessibilities Guidelines (ADAAG) compliant [18].
- A large portion of evacuations are considered non-panic situations [17], so the first studies should involve general crowd movement scenarios (foundation).

Individuals with Disabilities

- Individuals with disabilities have a more profound impact on the movement in a crowd.
    - Greatly slower than 'normal' flow
    - Take up more space that the 'normal' flow
    - Although a small percentage of the crowd, can have large impact on crowd movements
- As emergencies happen, more disabilities may form due to physical, psychological, and emotional stress (walking wounded).

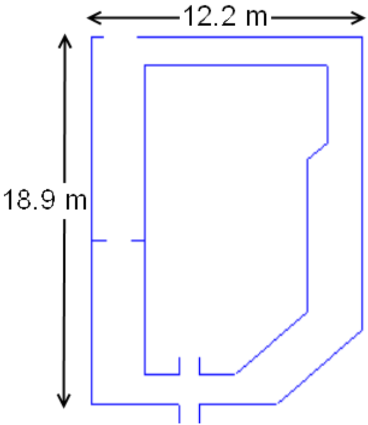
Goals and Needs

- Dissertation Goals/Needs :
  - Large-scale crowd experiments involving the diverse types of mobility related individuals with disabilities.
  - System to collect experiment data and analyze it, based on such experiments.
  - Using gathered analysis, determine differences or characteristics that can be modeled.
  - Create a model to capture some important characteristics observed in the empirical data.
  - Suggest possible future frameworks to assist in evacuations involving individuals with disabilities.

Experimental Need and Setup

- Use video tracking to gather heterogeneous data on a series of crowd experiments with various combinations and densities with and without individuals with disabilities.
- Study impacts of built environment through 45 degree and 90 degree corners, bottlenecks, and doorways that are all Americans with Disabilities Act Accessibility Guidelines (ADAAG) compliant.
- Track differences accurately enough (0.3 m) to separately identify group interaction and differences.
- A circuit would be built with various built environments with the desire to gather and identify data across the entire circuit.

Experimental Need and Setup



Experimental Need and Setup

- Large-scale experiment would need 60-100 participants to fill to reasonable capacity levels.
- Also the required need to analyze similar movements in stairwells, thus the system must handle vertical change.
- The experiment will involve paying participants, so any collection means need to be reliable and efficient.

Performance Goals

- Obtain separably identifiable trajectory data of pedestrians for different group analysis and analysis of movement.
- Accuracy must be within foot step or 0.3m.
- System must be able to handle large numbers of participants in a crowded environment (60-100).
- Pedestrians must be identifiable between cameras as one camera likely cannot cover the entire circuit.
- System must also handle height change due to different groups of disabilities and the stairwell.
- Reliable and robust to human error and action.

Resource Limitations

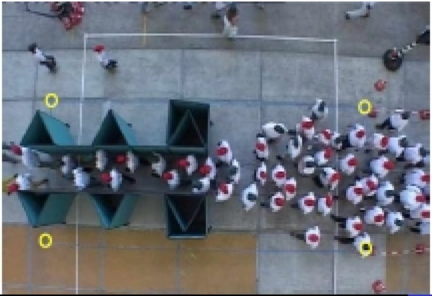
- Financial means split between camera system and future RFID system, excludes many potential systems automatically.
- Large-scale experiment to occur in one year so limited time for research, development, and implementation
- Limited personnel to develop and implement data collection system
- Any data collection system must be within budget, researched, developed, tested, and implemented within one years time of grant start.

Data Collection Examples

- Research to track pedestrians in sparse environments across large open areas [20,21].
- Track flow and homogeneous conditions in crowded environments [22-24]
  - Cannot separate or track individuals with disabilities
- Some ability to recognize bicycles [25] and wheelchairs [26].
- Two promising data collection systems that have some ability to separably track and collect data.
- Video from above prevents occlusions, easier to track.

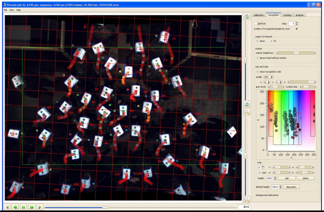
Previous Data Collection Techniques

- One study to track different groups through flows using colored hats (uni and bi directional) [27].
  - Only separably identifiable within single camera frame and hat color.
  - no height information so trajectories are only relative to each other, not as accurate.



Previous Data Collection Techniques

- One study to track each individual using marker hats with color information for height range [28].
  - Still only separably identifiable within single camera frame.
  - Color information on height only groups into height range, thus still not very accurate. Requires gathering everyone's height.
- Given lack of affordable off the shelf option with heterogeneous tracking ability, a new system must be created to suit the experiment needs.



Augmented Reality

- ARToolkit (must have individually created patterns)
  - A desire to have ˜100 pedestrians per day.
- ARToolkit dependent on number of patterns visible. Lacks robustness to lighting changes.
- ARToolkitPlus [32,33]:
  - 4096 BCH ID-encoded patterns already available.
  - Up to 512 on a screen traceable at a time.
  - More robust to light conditions, shade issues, etc.
  - Developed for mobile devices, low footprint of libraries.

Camera Selection

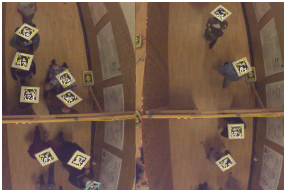
- Circuit to be built in gym at USU, with 8 meter ceiling heights.
- IDS Imaging [34] cameras chosen for higher resolution, faster frame rate of 50 fps, and power-over-ethernet.
- 3.5mm wide angle lens [35].

Camera Selection

- Light enough to suspend safely above participants.
- Cover as much area as possible while still tracking well.
- 50 frames per second to reduce unpredictable actions interfering with tracking.
- Single cabling for power/comm reduce suspended cabling and potential problems.

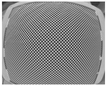
Software Development

- Combine with video processing libraries called Cinder [32,36], to create program for debugging, analysis, and calibration.
- Analysis should be post-processing, instead of live recording, etc.
- Yellow circles implies hard lock on tracking, blue circles implies pattern found but not recognized.



Camera Calibration

- Wide angle lens to severe for traditional approaches recommended [37,38].
- Use Omni Camera Calibration Toolbox to calibrated over lens [39,40].
- Resultant accuracy of a static pattern is 5-15cm depending on location in camera field.

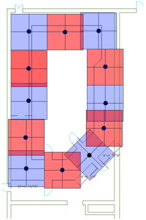


Circuit Camera Determination

- Ground truth trials to find best accuracy dependent on camera height.
- Determined 4.2 m camera height gives 2.1 m radius of best accuracy.
- 7-17cm accuracy dependent on walking speed of pedestrian and 50 fps shutter.
- 0.3-0.5 m accuracy in vertical, need to record heights for stairwell testing.

Circuit Camera Determination

- Twelve Cameras to cover edge of circuit and provide best accuracy
- Two cameras to cover two stairwells to be studied.
- Cameras placed to ensure best accuracy over centers of built environment aspects (corners, doorway, etc).
- Cameras placed to cover entire walking circuit.



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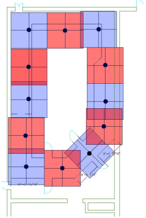
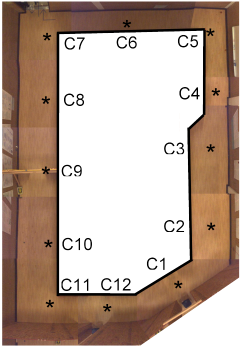


System Implementation

- Circuit built from wood in USU Motion Analysis Lab, 8 meter high ceilings (former gym)
- Camera's suspended using rope over steel girders and a child's food bowl [41] to act as a gimble for easier adjustment.

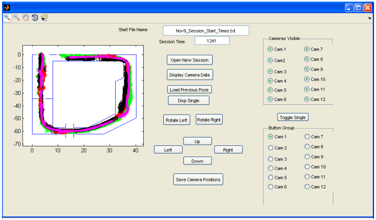


Recording System

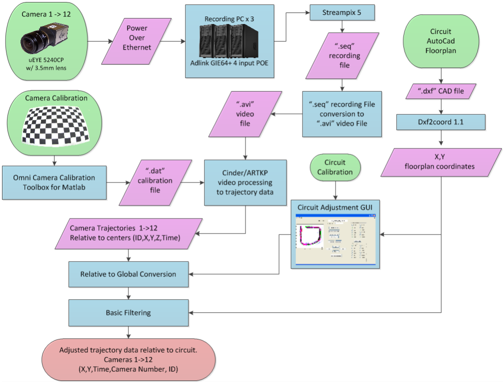
- Record twelve 50fps cameras at high resolution over period of 8 hours.
    - One days worth of recording, uncompressed videos, takes up 2TB of space.
- Three 8-core computers with 32gb of memory, each handles 4 cameras.
- Power and communication through Adlink GIE64+ POE cards [42].
- Recording suite, Streampix 5 [43].
- Ten minute sessions to reduce processing and recording intensity on computer

Circuit Camera Calibration

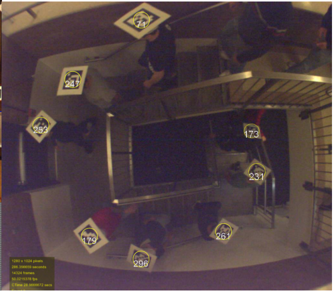
- Cameras not guaranteed to be hung properly
- Variations in height and camera positions different from predicted.
- Need to adjust camera data to proper positions in circuit and convert data to be global to the circuit



Camera System Data Flowchart



Data Collection



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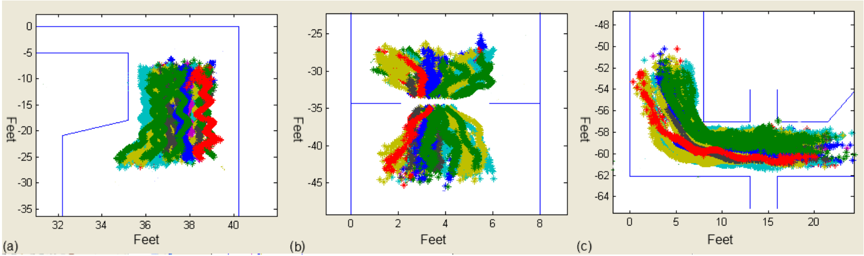

Data Collection