Measuring Human Movement Patterns and Behaviors in Public Spaces

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Measuring Human Movement Patterns and Behaviors in Public Spaces

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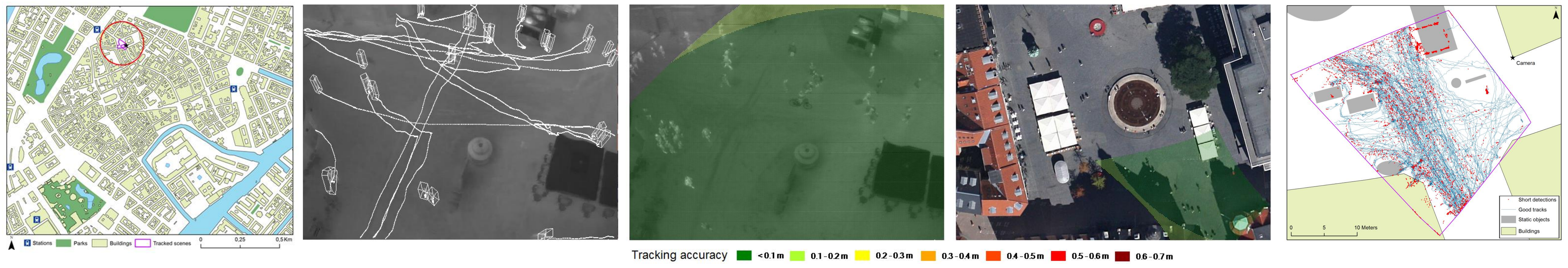


Introduction

Cities require reliable data on pedestrian movement and behaviors to evaluate the use of public spaces. Studies of such micro scale movement behaviors are challenging as they demand accurate and simultaneous tracking data for several individuals who may move close together, and where the movement of each individual depends upon interactions with others as well as on the physical layout of the place and attractors in the space traversed.

To collect and analyze data for such studies, we propose a system using thermal cameras and Computer Vision (CV) technology combined with the analytical virtues of Geographical Information Systems (GIS) to track and assess pedestrian dynamics and behaviors of the everyday movement patterns and situations occurring in urban streets and plazas

Method

Our method enables recording of georeferenced positions of individuals in a scene 30 times per second. By using a homography matrix to transfer between image and real world coordinates the spatial accuracy of the tracking is about 25-100 cm depending on people's position in the camera's Field of View (FOV). This allows for the analysis of behavior and attendance at a fine scale compared to other methods for pedestrian behavior monitoring [1,2].

The use of thermal cameras has the advantage over normal cameras that they can operate independent of light, and in many situations they perform better with Computer Vision software as segmentation of moving objects is easier in thermal videos (see table). At the same time concerns for privacy issues when tracking people can be neglected since the cameras literally just record the temperature of the city life with no risk of revealing individuals identity from the video stream. Thus the technique ensures privacy by design and is legal to apply.

Furthermore the prices of thermal cameras continue to be lowered at the same time as the resolution keeps improving [3].

	Pros	Cons
Thermal camera	Easier segmentation Independent of light No privacy issue	Re-identification difficult More expensive Fair resolution
RGB camera	Re-identification possible Cheap Sensors High Resolution	Sensitive to light Privacy issues Shadows

Table: The table describes the pros and cons in relation to using thermal cameras vs. normal RGB cameras for Computer Vision tracking of people in outdoor urban scenes

This add to the practical applicability of thermal sensors for pedestrian behavioral studies. Our method builds on previous CV work by [4,5] .

Pilot study in Copenhagen

In June 2013 we conducted a pilot study at the Kultorvet plaza in Copenhagen which is a pedestrian zone with a continuous flow of pedestrians from several directions that need to negotiate each other. A single state-of-the-art uncooled thermal camera with a resolution of 640x480 pixels (Axis Q1922), a lens with a focal length of 10 mm, a viewing angle of 57º, and a 30 fps camera frame rate was used. Background subtraction was applied to detect people. To assess the quality of the trajectories generated by the CV software, Ground Truth (GT) trajectories were digitized manually for all individuals passing or residing in the scene in the five minutes of video analyzed. The manual digitization was done in the T-Analyst software developed at Lund University [6].

Analysis of behaviors

Tracks of people walking alone or in social groups of different sizes were recorded, as well as people waiting, people having a conversation, and people dragging their bikes or pushing prams or wheelchairs. While going through the videos to digitize the GT tracks we have identified characteristic movement behaviors such as meeting, flocking, avoidance, and following a leader [7]. Interesting individual movement patterns were also found. An example of this is a "facer" working for a charity organization attempting to stop people in the street to recruit them. The behavior of the facer and the people he approaches is used here to show the extraction of tracks for individual's behaviors.

Outlook and perspectives

Based on the data and experiences gained from the pilot study we are preparing a full scale experiment using multiple thermal cameras with overlapping FOVs to be carried out over a sustained period of time.
The study is to be combined with sampled periods where qualitative data from human observations on the street level will be collected as well. Further research will be to develop advanced methods in GIS to enable extraction of behavioral parameters for different classes of tracks that can be used to calibrate models of pedestrian movement.

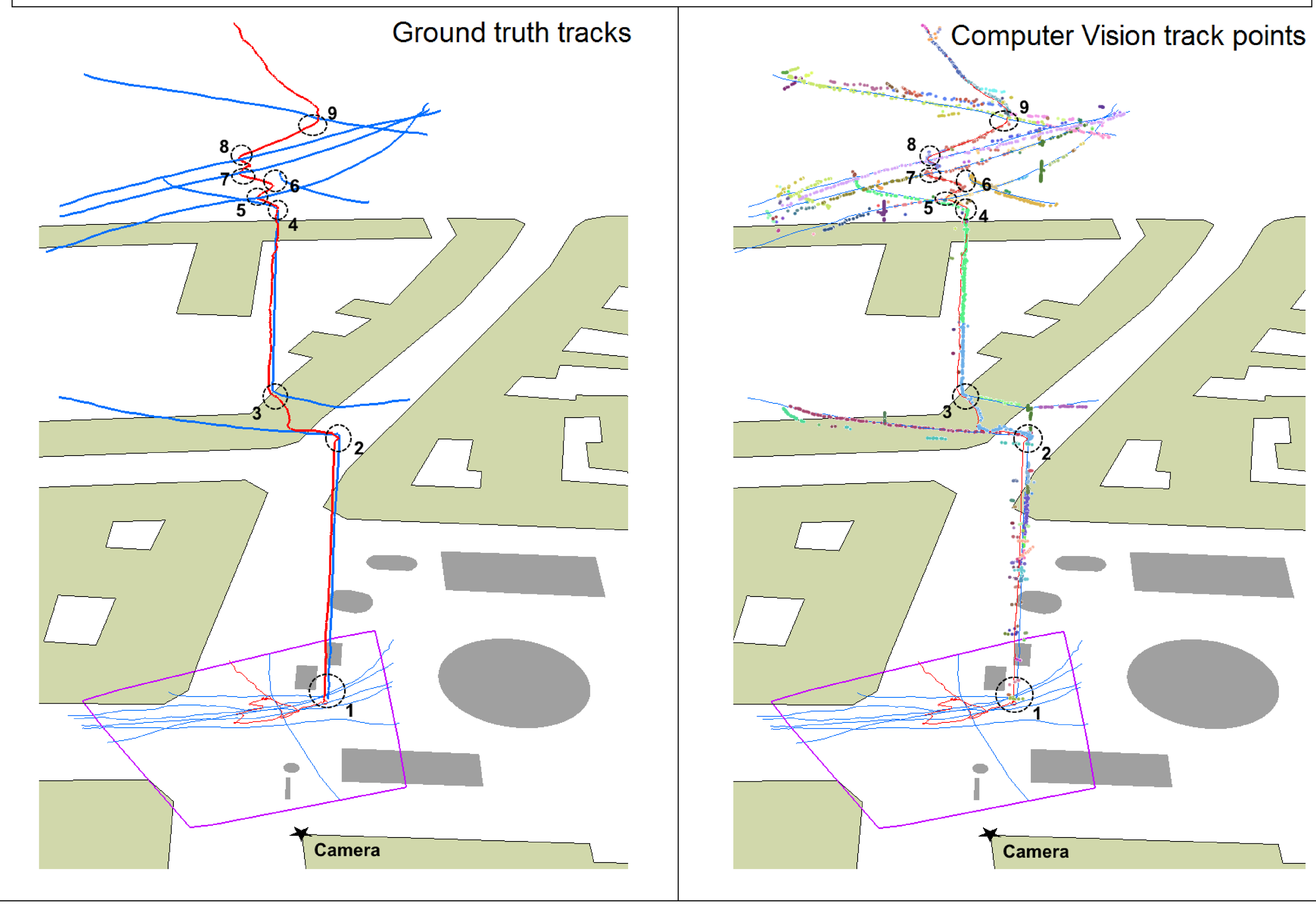
Our approach to tracking urban public life should be seen as a supplement to the traditional qualitative and intuitive manual methods for data collection used in studies of urban public spaces and qualities [8,9]. It is the aim that our work can contribute to the development of new digital methods in this field.

The five figures above:

- The first figure from the left displays the location of the Kultorvet plaza in relation to central Copenhagen.
- The second figure shows a scene from the thermal video as it looks in the T-Analyst software used for manual annotation of ground truth tracks. 3D rectangles of 0,5x0,5x1,8 meters are placed frame-by-frame on the moving pedestrians in the video sequence annotated.
- The third figure visualizes the spatial accuracy of the tracks obtained from the camera. The accuracy is calculated from the homography matrix relating the image pixel coordinates to real world coordinates.
- The fourth figure shows the newest orthophoto of the tracked plaza with the tracking accuracy layer overlaid in the area covered by the camera FOV.
- The last figure shows the tracks (blue) obtained from the Computer Vision algorithm. The overall movement patterns are clearly seen. Movement of less than three seconds is marked in red as false positive detections.

The figures below:

The nine images at the bottom serve as an example of individuals' behaviors tracked with the thermal camera. The sequence follows a "facer" working for a charity organization. He is seen trying to approach people passing in the plaza and recruit them as members of the organization he represents. The numbers below the images refer to the marked circles on the two 3D visualizations of the tracks depicted in the space-time cubes (STC). The left STC shows the georeferenced tracks obtained from the manual Ground Truth (GT) annotation. The right STC shows the corresponding track points obtained from the Computer Vision (CV) tracking algorithm that are within one meter and one second of the GT tracks. This is shown to visualize the performance of the CV tracking. Each unique ID number of the track points are distinguished by color. It is clear that the IDs change more often than they should as compared to the GT tracks. This indicate that the CV tracking cannot yet resolve ambiguous situations perfectly.



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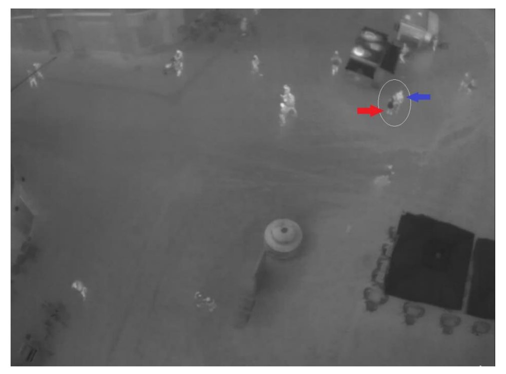
Video visualizations

http://youtu.be/8sN7CVFhPwg

http://youtu.be/16p7I9YwoHs



1. The facer is talking to a person

2. End of conversation and split up

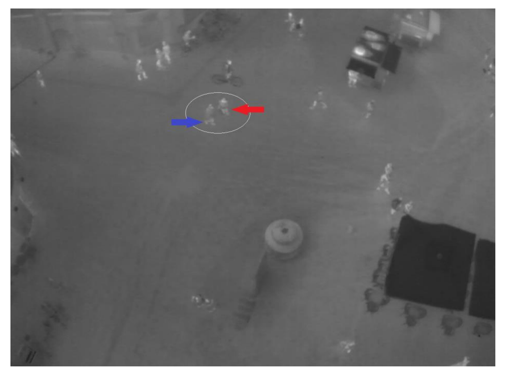
3. Approaches person successfully

4. End of conversation and split up

5. Approach unsuccessful

6. Tries new approach but unlucky

7. Tries new approach again



8. Approach unsuccessful

9. Decides to take a break