Summarization and Visualization of Pedestrian Tracking Data

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***Abstract*—We present a summarization and visualization technique for large-scale traffic path data. The research aims to visually distinguish the amount of similar traffic, by representing the similar traffic as bundles of lines. Our technique firstly quantizes the collection of paths, then categorizes the segmented paths, and finally renders the bundles of the segments. Our implementation also provides a graphical user interface (GUI) that allows users to interactively explore the various types of data, so that they can adjust the degree of summarization by controlling parameters in the GUI. The technique can visualize various kinds of path data recorded as chronologically ordered positions which form sequential segments, acquired from movies, sensors, and computer simulations. One of the features of the technique is that it can effectively visualize paths in the place where there are not expressly constructed ways. This paper demonstrates the effectiveness of the technique by applying it to two types of path data, where one is acquired by Radio Frequency IDentification (RFID) sensors, and the other is extracted from a movie.**

***Keywords*-Visualization, summarization, movie tracking, RFID.**

I. Introduction

Pedestrian traffic flows are critical factors for assessment of lands, buildings, and advertisements. Moreover, improvements of efficiency based on these flows are required in communal and public facilities such as medical institutions and airports. Therefore, observation of traffic paths of people is useful for various purposes. Recent computer vision and sensor technologies have provided the means to acquire accurate data about such traffic paths.

There have been several reports on the summarization and visualization of traffic flows of large numbers of people. Reported techniques can be categorized into two approaches: drawing flows into geographic spaces, and drawing as graphs. The technique presented in this paper can be categorized into the former approaches. Here, it may be difficult to look at or understand the paths with many of the early techniques, because the techniques directly draw the trajectories of the paths onto the display and therefore many of the paths clutter up the display results. Traffic summarization is therefore important to obtain more comprehensive visualization results in the geographic spaces. Several recent techniques have improved the visual representation of the paths. Some of the techniques attempt to integrate them onto known ways or automatically selected representative paths [5] [10]. However, there are still situations that cause these techniques to perform poorly. There may not be (or we cannot recognize) representative paths with certainty, when traffic is very tangled. Some of other techniques attempt to partition the geographic spaces and calculate transitions between adjacent regions [3] However, it may be difficult situations that the techniques cannot effectively partition the geographic spaces. For example, it may be difficult to discover characteristic regions of the flows when there may not be expressly constructed ways in wide spaces, such as parks, squares, and scrambled crossroads, and therefore pedestrians freely walk. We therefore think it is interesting to develop summarization and visualization techniques for such paths which can be used in a wide variety of environments.

This paper presents a technique for summarization and visualization of traffic paths which is available whether there are expressly constructed ways or not. The technique assumes that there are many paths across the given geographic space, and the paths consist of sequential points in the space. The technique firstly quantizes the paths with a grid surrounding the 2D space, by connecting intersection between grid-lines and the paths It then collects closely generated segments in each of rectangular regions divided by the grid. It then merges them by the average segments, and optionally connects the merged segments applying Hermite curves. Finally, it draws the segments with interactive operations. Also, the paper introduces two representative case studies: paths of pedestrians in a building tracked by RFID sensors, and paths of them in a wide space of a university campus captured from a movie file. These case studies demonstrate how the technique performs whether there are expressly constructed ways or not.

II. Related Work

Many reports have discussed the visualization of traffic paths in the context of geographic spaces. Many early works straightforwardly draw traffic paths [4] [6]; however, it is obviously problematic for large-scale tracking data due to overlapping and cluttering of the drawn paths. Summarization of tracking data assists to realize comprehensive visualization of large-scale path data.

Andrienko et al. presented a technique that generates primary flows of crowds and then displays the results using

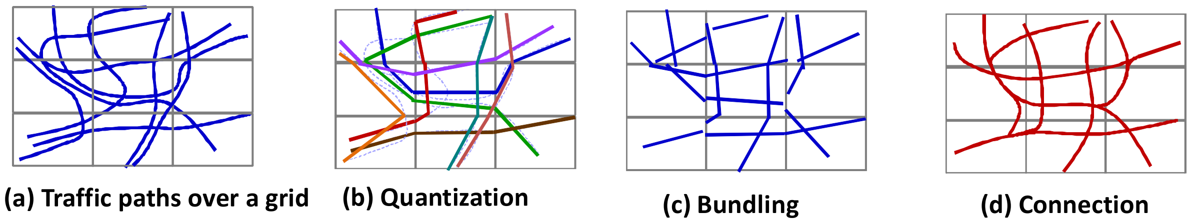

Figure 1. Brief procedure of the presented technique. (a) Generate a grid in a 2D space which traffic paths are tracked. (b) Quantize the paths by intersections with the grid-lines. (c) Bundle the quatized paths inside each grid subregion. (d) Connect the bundled paths by Hermite curves.

many ranged straight arrows [2] [3]. The technique extracts and groups characteristics points of paths, then partitions the regions, and finally calculates the transitions between adjacent territories. Consequently it represents the summarized paths as segments connecting specific adjacent points. The representation works very well with their examples including car traffic data; however, it is not clear if it works well with the tangled traffic data in freely walking wide spaces (e.g. parks or scramble crossroads), because it may be difficult to extract meaningful characteristic points from the tangled traffic.

At the same time, several other techniques attempt to generate primary flows of crowds and then represent them as thickness-varied arrow curves [5]. Such approach is usually appropriate not only for spaces that expressly constructed ways (e.g. roads or corridor) but also for wide spaces. However, primary flow extraction is not an easy problem. It may often fail to discover really important flows, or involuntarily merge different types of flows.

Several other reports expresses the summarization and visualization of traffic paths with graphs [7], [8], [9].

III. Summarization and Visualization

This section presents a new summarization and visualization technique of traffic paths. The technique first quantizes the path data and converts it into a set of rougher segments, because the data may be too fine and therefore contain meaningless noises. The technique then collects and categorizes the segments based on their directions, and bundles the categorized segments as average segments. Since the bundled segments may be discontinues, the technique optionally provides a process to smoothly connect them applying Hermite curves. Finally, the procedure interactively renders the summarized segments.

Following is the brief procedure of the proposed technique, and its illustration is shown in Figure 1:

1) **Quantization:** map a grid onto the 2D path space, calculate intersections, move intersections onto the vertices of the grid, and construct the quantized paths.
2) **Summarization:** categorize the segments of the quantized paths for each rectangular space, unify geometrically overlapping categories, bundle segments belonging to the same categories. Optionally, connect the bundled segments applying Hermite curves.
3) **Rendering and interaction**.

A. Path Acquisition

We formalize a set of paths as $S = \{P_1, ..., P_n\}$, where P_i is a path and n is the total number of paths. A path consists of a sequence of passing points, $p_i = \{p_{i1}, ..., p_{im}\}$, where p_{ij} is the j-th point of the i-th path, and m is number of points of the i-th path. The point p_{ij} contains the time t_{ij}, and x/y-coordinates x_{ij} and y_{ij} in a 2D space.

We transformed an open RFID sensor data introduced in Section 4.1.1 into the above data structure. We also acquired an example of the traffic path data introduced in Section 4.1.2 from movie files taken by a fixed camera. The presented technique summarizes the traffic path data by constructing clusters of similar paths, and draws them as a set of segments.

The reader should note that traffic path data can come from a variety of different sources. While we discuss data acquired from movies and sensor data, data can also be produced from computer simulations.

B. Quantization

The technique then quantizes the set of paths. It maps a grid onto the 2D path space as shown in Figure 2(Left)(1). The grid lines are assumed to be much bigger than the average interval of the adjacent two points p_{ij} and $p_{(i(j+1))}$. The technique then calculates intersections between the paths and grid lines, shown as red circles in Figure 2(Left)(1). Let the intersections of the i-th path be $P_i^{'} = \{p_{i1}^{'}, ..., p_{il}^{'}\}$, while l is the number of intersections between the i-th path and grid lines. It then quantizes the paths by moving the intersections onto the vertices of the grid, shown as blue circles in Figure 2(Left)(1). Let the quantized intersections of the i-th path be $P_i^{''} = \{p_{i1}^{''}, ..., p_{il}^{''}\}$. Finally, the technique constructs the quantized paths by connecting the vertices of the grid, as shown in Figure 2(Left)(2). Here, the double-ringed, enlarged circles in Figure 2(Left)(2) denote that the quantized path passes these points twice.

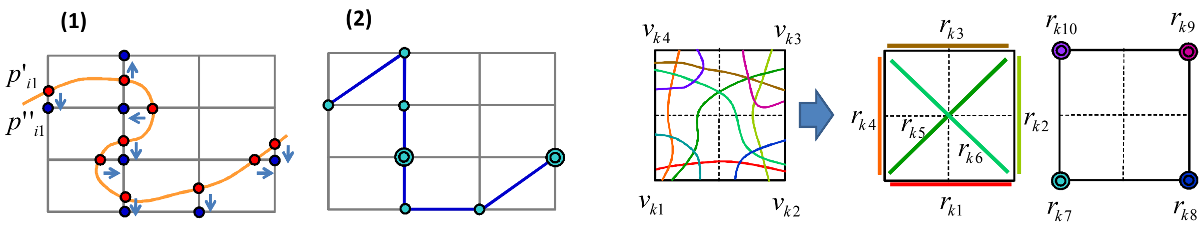

Figure 2. (Left) Quantization of paths. (Right) Patterns of path segments. Division of a rectangular space into four subspaces, and 10 patterns r_{k1} to r_{k10} according to quantized positions of start and end points of the segments.

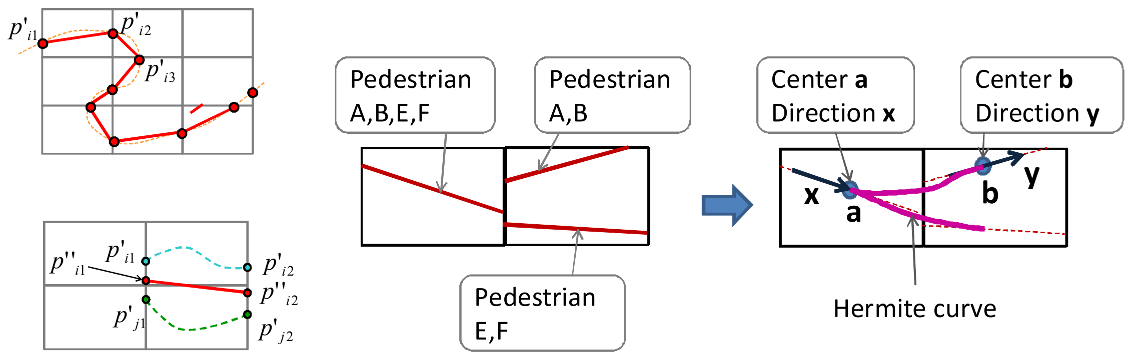

Figure 3. (Left) Bundling of segments. (Upper-Left)If there is only one segment in the patterns, the technique treats the segment as is. (Lower-Left)If the pattern has more than one segment, the technique treats the average of the segments as a bundled segment. (Right) Connection of bundled segments applying Hermite curves.

C. Collection, Categorization, and Bundling

The technique then categorizes the segments of the quantized paths for each rectangular space divided by the grid. Let the k-th rectangular space be r_k, and its four vertices be v_{k1} to v_{k4}. The technique collects all the intersection segments $P'_{ij}P_{(i(j+1))}{}'$ of the all paths P_1 to P_n passing through r_k. It then categorizes the segments into 10 patterns, r_{k1} to r_{k10}, according to the combination of the two vertices of the segments after the quantization. Figure 2(Right) denotes the ten patterns drawn in ten colors. Here, four patterns r_{k7} to r_{k10} denote that two end points of the quantized segments are at the same positions. Finally, the technique unifies geometrically overlapping categories. Supposing a rectangular space r_p and its lower adjacent r_q, the technique unifies the geometrically overlapping categories, r_{p1} and r_{q3}, r_{p7} and r_{q10}, r_{p8} and r_{q9}, respectively.

The technique then bundles segments for each pattern of each rectangular space r_k. Here, the technique divides the process according to the number of segments. If a pattern r_{pq} has only one segment $p'_{ij}p'_{(i(j+1))}$, the technique treats the segment as is. Figure 3(Upper-Left) shows an illustration that such segment is rendered. Note that the technique renders the segments connected by the intersections before the quantization p'_{ij}. If the pattern r_{pq} has more than one segment, the technique calculates the average path of the segments as a bundled segment. Figure 3(Lower-Left) shows an example of an average path. Here, a sky blue segment p'_{i1} p'_{i2} and a green segment p'_{j1} p'_{j2} are the two segments those vertices are quantized to the same two vertices p''_{i1} and p''_{i2}. In this case, the technique treats the average of the two segments as a bundled segment, shown as a red segment in Figure 3(Lower-Left).

D. Connection of bundled segments

Segments bundled by the above process may be often discontinuous. The discontinuity is especially observable when we measured the paths of pedestrians at freely walkable spaces. For example, such discontinuity is not observable in the result at colliders of a building, shown in Section IV-A; however, it is especially observable in the result at free space of a university campus, shown in Section IV-B. For this problem, we developed a technique that connects the adjacent bundled segments which share at least one common pedestrian. The technique applies Hermite curves to smoothly interpolate the gaps between the adjacent bundled segments. Figure 3(Right) illustrates the process. The technique firstly finds pairs of segments which belong to adjacent grid-rectangles, and share at least one common pedestrian. It then generates Hermite curves connecting centers of the segments, where tangent vectors of the end points of the Hermite curves correspond to the direction of the segments. In Figure 3(Right), **a** and **b** denote the centers of the two segments, and correspond to the positions of the end points of the Hermite curve. Also, $\mathbf{x}$ and $\mathbf{y}$ denote the directions of the segments, and correspond to the tangent vectors of the end points of the Hermite curve.

IV. Case Studies

This section introduces two case studies to demonstrate the capability of our path visualization.

A. Paths Acquired by RFID Sensors

First, we show the result of the visualization of paths acquired at a place where there are expressly constructed ways. The data is drawn from evacuation routes in a certain building, acquired by RFID sensors and published on the Web [1]. Figure 4(Left) shows a map of the building. In this figure, a bomb explodes at the bomb mark. People then evacuate through the doorways that have arrows and are circled in red. In a disaster situation such as this, lives will be saved if everyone can leave the building as quickly and orderly as possible.

Figure 5 (Left) shows captured paths. Many of paths overlap in the figure and therefore it is difficult to understand the quantity of overlapping paths from the figure, because many people may go along the same way during the evacuation. Figure 5 (Center) shows an intermediate result in which the walks are blurred by the quantization. Figure 5 (Right) shows a visualization result by the presented technique, which adequately represents the degree of congestion of the paths. Time required to escape from the building can be reduced if the people escape along less crowded ways for such refuge. We think this visualization result will suggest the improvement of the refuge course.

We discovered a thickened path at a left part in Figure 5 (Right). When we see the part more in detail, though it is one-way path, we discovered that in this part the summary line is thicker than the adjacent parts. We wondered why it was thickened. If people could smoothly escape from the building, we would not see such thickened segment. Looking at a video displaying the RFID sensor data, we could discover evacuees losing their ways. As just described, we could discover an extreme behavior of evacuees from the visualization result immediately, and understand the problem by looking at the video. We understood how important it is to make the escape route comprehensible from this discovery.

B. Paths Captured from Movies

We were also challenged to attempt to visualize paths that were acquired at a place without expressly constructed ways.

We recorded a movie file around a door of a cafeteria of a university for 30 minutes, from the higher floor of another building. Figure 4(Right) shows the position of the door of a cafeteria, garbage boxes, and vending machines. Our current implementation detects moving objects by Mean-Shift method, and assigns identical numbers to each of the objects. Our technique then extracts positions of the moving objects in the image space for each frame. We manually removed positions if the data contained the paths of non-human objects.

Figure 6 (Left) shows captured paths. Figure 6 (Center) shows an intermediate result, hence instead of looking like a very jagged line, it appears as a smoother arc because there are fewer sample points. Figure 6 (Right) shows a visualization result by the presented technique. The technique controls color and thickness of segments according to the number of passing persons, so that users can understand main flows of the traffic. We captured the movie around lunch time; therefore, we can observe the main flows from a lecture building to the door of the cafeteria. The result shows that the technique effectively simplified the path data and highlighted main flows. The example demonstrates that the presented technique can effectively visualize paths in places without expressly constructed ways.

Figure 7 shows the result of connection of merged segments. It is observable that merged segments shown in Figure 6 (Right) are somewhat discontinues; however, they are smoothly connected by applying Hermite curves and therefore the result is more comfortable to carefully observe. The technique can generate different resolutions of connected flows by varying the resolution of grids. This operation is useful for level of detail control of visualization results. Our implementation realizes interactive level of detail control since it spends less than 100 milliseconds for quantization, bundling, and connection with this dataset.

We were able to discover the main route as a result of observation of these results. Moreover, we were able to find that there were few people walking to the right side of the garbage box, though there were many people who walked in front of the garbage box. We understood that there were many people who stopped by the garbage box, before entering the cafeteria after leaving the main route, or after exiting the cafeteria before joining the main route. We think that such observation is useful for deciding how to arrange objects around the walking spaces.

V. Conclusion and Future Work

We presented a technique for summarization and visualization of large collections of traffic paths As demonstrated in Section IV-B, the presented technique can effectively visualize paths in the place where there are no expressly constructed ways, which is an improvement over existing techniques that can only visualize results in places where there are expressly constructed ways.

As an on-going work, we are implementing a technique to convert the rendered segments into fewer numbers of smoothly connected curves. Another important issue is representation of direction of flows. Our current implementation does not consider the direction of segments during the

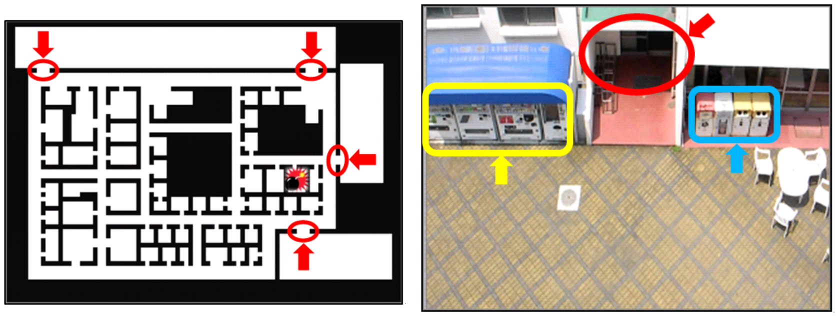

Figure 4. (Left) Map of the building. Scenery of around a door of a cafeteria of a university. (Right) (Red: Door of cafeteria, Blue: Garbage boxes, Yellow: Vending machines.)

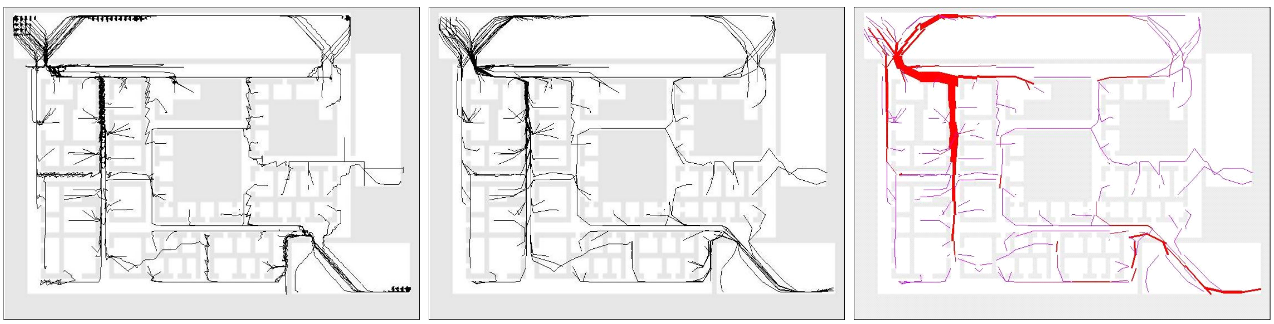

Figure 5. Rendering segments of the paths acquired by RFID sensors. (Left) The technique renders corresponding single segments as-is. (Center) The technique calculates intersections between the segments and grids, connects the intersections by straight segments, and renders the segments. (Right) The technique calculates the average of corresponding segments and renders according to relative density.

Figure 6. Rendering segments of the paths captured from a movie file. (Left) The technique renders corresponding one segment as is. (Center) The technique calculates intersections between segments and grids, connects the intersections by straight segments, and renders the segments. (Right) The technique calculates the average of the corresponding segments, and renders according to relative density.

categorization and rendering, so we would like to extend the implementation so that we can represent these directions.

The presented technique is not limited to path data obtained from movies and sensors: it can also visualize simulation-based path data. We would like to apply such path data to the presented technique in a future work.

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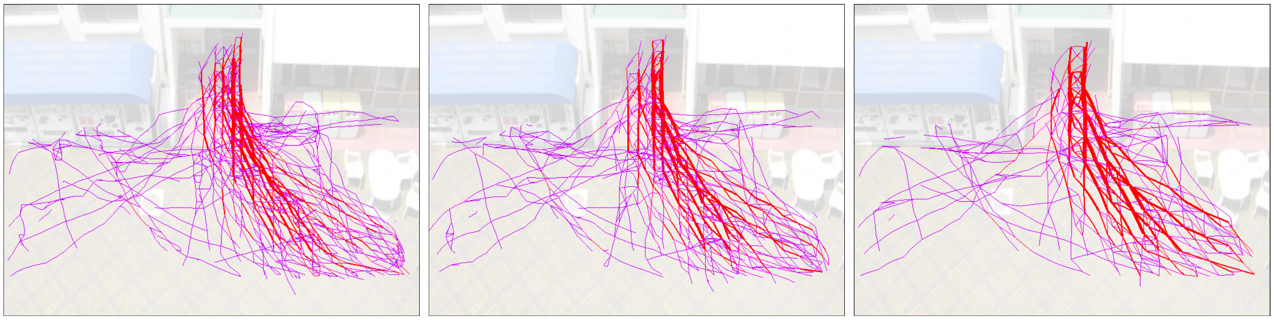

Figure 7. Connection of merged segments applying Hermite curves over various resolutions of grids. (Left) Using a grid dividing into 20×20 rectangles. (Center) Using a grid dividing into 15×15 rectangles. (Right) Using a grid dividing into 10×10 rectangles.

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