Trajectolizer: Interactive Analysis and Exploration of Trajectory Group Dynamics

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***Abstract*—Mining large-scale trajectory data streams (of moving objects) has been of ever increasing research interest due to an abundance of modern tracking devices and its large number of critical applications. A challenging task in this domain is that of mining *group patterns* of moving objects. *Group pattern mining* describes a special type of trajectory mining that requires to efficiently discover trajectories of objects that are found in close proximity to each other for a period of time. To this end, we introduce *Trajectolizer*, an online system for interactive analysis and exploration of trajectory group dynamics over time and space. We describe the system and demonstrate its effectiveness on *discovering group patterns on trajectories of pedestrians*. The system architecture and methods are general and can be used to perform group analysis of any domain-specific trajectories.**

***Index Terms*—Trajectory mining, group pattern mining**

I. Introduction

The vast deployment of tracking devices and advancement of motion video analysis techniques have resulted in tremendous trajectories being captured over time. Analyzing trajectories of moving objects, such as persons, vehicles or animals to extract interesting patterns is of utmost interest in wide-range of applications [1]. *Group pattern* mining describes a special type of trajectory mining task that seeks to efficiently discover moving objects, such as *pedestrians* that are found in *close proximity* to each other *for a period of time* [2]. This is an important step towards studying and understanding the relationship dynamics of these objects (pedestrians), including *group gathering* (people coming together), group membership (people spending time together) and *group dispersion* (people distributing over a wide area). Group analysis can reveal interesting insights that are otherwise not easily observable.

A number of systems exist for trajectory analysis that primarily focus on descriptive statistics of individual trajectories (e.g., distance traversed, elapsed time, etc.), comparative analysis of univariate properties (e.g., arithmetic mean, standard deviation, etc.), and domain-specific information, such as trajectory density maps. However, these systems disregard analysis related to group dynamics due to its computational complexity and ambiguity of grouping semantics. It is therefore essential to design and develop systems that facilitate interactive analysis, exploration and visualization of group patterns of trajectories over time and space. Such systems can be used to validate novel methods of group pattern discovery and more importantly, they can be used to perform a more refined analysis of trajectories that consider the pairwise relationships (or interactions) among different moving objects.

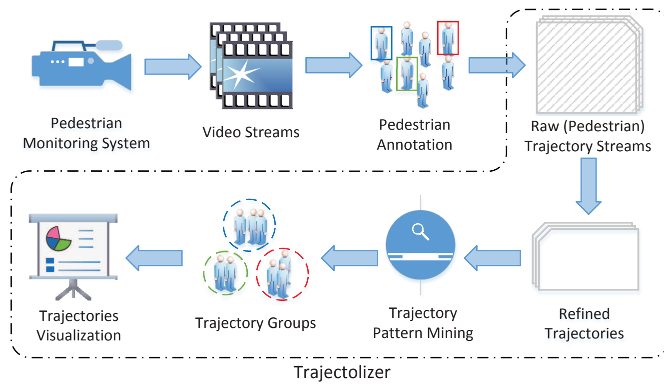

Fig. 1: A flowchart illustrating *Trajectolizer*'s analytics process

Our proposed system, *Trajectolizer*[1], aims to address these limitations. In particular, given trajectory streams captured by motion analysis video, it allows to perform analysis of the interactions that occur among the moving objects (e.g., pedestrians) in the scene, including information about the length of the interaction, group formation, group membership, group dispersion and more. *Trajectolizer* provides efficient and effective analysis and visualization of grouping patterns that can support a variety of useful applications ranging from monitoring physical areas, such as shopping malls, train stations, stadiums, and airports to supporting pedestrian behavioral studies. Pedestrian motion video analysis raises additional challenges for the problem of interest. In fact, pedestrian scenes render the analysis more challenging, as individuals are often intermixed with the crowd. We address these problems in a data preprocessing phase and discuss potential implications. Our proposed analytics system and methods are not domain-specific and can be applied to any trajectory data (not necessarily representing pedestrians).

II. Overview of *Trajectolizer*

In this section, we provide an overview of *Trajectolizer* that allows to analyze group behavior of pedestrians given only their trajectories in the scene. The complete process is depicted in the flowchart shown in Fig. 1. Pedestrian trajectory streams are generated from analyzing video streams captured by cameras. Alternatively, pedestrian trajectories may be collected from GPS tracking devices, such as mobile phones or dedicated devices for non-pedestrian related applications.

[1] *https://sites.google.com/view/pedestrians-group-pattern/*

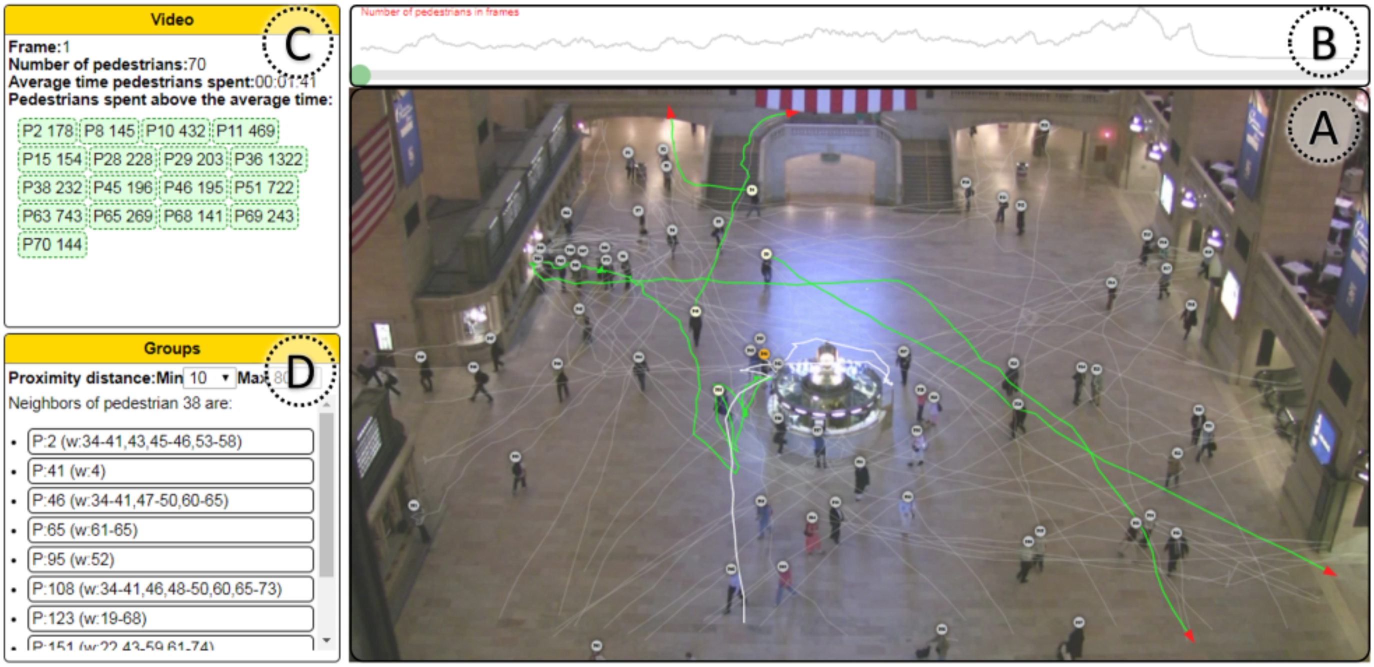

Fig. 2: A snapshot of *Trajectolizer*'s User Interface that allows interactive exploration of pedestrian trajectory group patterns.

Once the system receives trajectory streams, the preprocessing step is performed to refine the trajectories by means of data cleansing. End-users can customize this process by visualizing the refined trajectories and adjusting the preprocessing parameters. Let a set of N pedestrian trajectories $\mathbb{T} = \{\mathbf{p}_i : i \in N\}$, where $\mathbf{p}_i = \{(x_i^{t_1}, y_i^{t_1}), (x_i^{t_2}, y_i^{t_2}), \ldots, (x_i^{t_n}, y_i^{t_n})\}$ and $(x_i^{t_k}, y_i^{t_k})$ represents the xy-position of pedestrian i at time t_k. Then, given a user-specified proximity threshold τ and a time window w, we can perform trajectory group mining by grouping together trajectories $\mathbf{p}_i, \mathbf{p}_j \in \mathbb{T}$ that satisfy $\mathbf{D}_w(\mathbf{p}_i, \mathbf{p}_j) \leq \tau$. Here, $\mathbf{D}_w$ represents the distance between two trajectories i, j as defined in (1) and proposed in [3].

$$D_w(\mathbf{p}_i, \mathbf{p}_j) = \max_{\{t \to t+w-1\}} \sqrt{(x_i^t - x_j^t)^2 + (y_i^t - y_j^t)^2} \quad (1)$$

The resulting trajectory groups are then stored on the server for fast retrieval and interactive visualization.

Implementation Optimizations: In order to improve user experience, a number of implementation optimizations were taken into consideration to load only the minimum required amount of data and updating the visual components using asynchronous requests. *Trajectolizer* was developed using the popular *D3.js* open-source JavaScript visualization library [4].

III. Demonstration

A snapshot of the system's User Interface is shown in Fig. 2. It comprises of four main panels: (A) a video frame panel that shows the pedestrian IDs and trajectories in the current frame; (B) a timeline slider that allows to navigate to any particular video frame over time; it also provides information about the number of pedestrians in the video over time; (C) a descriptive analytics panel that shows information about the current frame, such as the frame number, number of pedestrians, average time that pedestrians spent in the scene, and list of pedestrians that stayed in the scene longer than an average stay time, and (D) a group information panel that shows analysis of pedestrian group behavior for different proximity threshold settings.

Demonstration Scenarios: During the demonstration, attendees will be able to use our system on a preprocessed trajectory dataset provided by [5] in order to perform analysis of pedestrians and discover group patterns. In particular, they will be able to: (i) project the trajectory of each pedestrian on the scene, (ii) identify the entry/exit gates each pedestrian has used to enter/exit the scene, (iii) visualize the location where pedestrians spent most of their time, (iv) report the length of a pedestrian's stay in the scene, (v) query about pedestrians who stayed in the station more than the average pedestrian did, (vi) query about *where*, *when* and *who* are other people that a certain pedestrian has been walking close to based on group pattern discovery methods proposed by Sawas et al. [3].

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