A Novel Interaction Paradigm For Exploring Spatio-Temporal Data

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Abstract
Complex spatio-temporal data is difficult to visualize and even further to interact with, especially by several users at the same time. However, visualization and exploration of such data are essential for experts to understand complex data environments, such as for mitigating the adverse effects of disease spread. This paper presents an alternative approach to that of current spatio-temporal data visualizations to access, interpret, and manipulate spatio-temporal datasets as a single user or as a team. Our approach uses tangible and visual tools such as mini-robots, tabletop displays and augmented reality tools, to facilitate the data exploration and interpretation. We also introduce a simple use case that illustrates one of the possible utilization of the system. While tangibles have been introduced to represent information, we are investigating manners in which we can depict even more complex datasets. Our system will provide a novel approach to manipulate 3D and 4D datasets that classic tools such as a 2D mouse or a tactile screen would not allow.

Author Keywords
Spatio-temporal dataset; data visualization; tangible interaction.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Spatio-temporal datasets are generated daily, to collect disease, migration or any other movement data. Their visualization usually includes animated visualizations or representations of space-time cubes [4], as illustrated in Figure 1. When facing such rich and complex data environments, the exploration and interpretation of data is crucial for acting on the systems, in order to, for example, limit the spread of a disease or identify traffic patterns. To facilitate this process, novel interactive tools are thus required.

Three key elements emerge from spatio-temporal datasets [1]. The first represents the object that is often the key entity. The second is the location of the movement they represent. Finally, the last key element is the time element that defines how fast the object moves or appears at a given location. For such three-dimensional datasets, finding a coherent and efficient interaction support to perform a set of operations to better explore these data or to manipulate them is a major challenge [2]. Solutions explored so far include the mouse, tangible user interfaces and mid-air interaction [3]. Using a 2D device, such as the mouse, for a 3D task greatly limits the efficacy of the interaction. Although tangible interfaces add physicality, it does not intrinsically provide feedback and raises issues in terms of the number of physical bricks that can be used simultaneously. Finally, mid-air interaction supports direct data manipulation, but may be limiting in terms of gesture detection and 3D perception (related to depth detection). These solutions, taken separately, allow limited manipulation of spatio-temporal datasets, but combined with other novel interaction technologies, can open radically new vistas for data exploration.

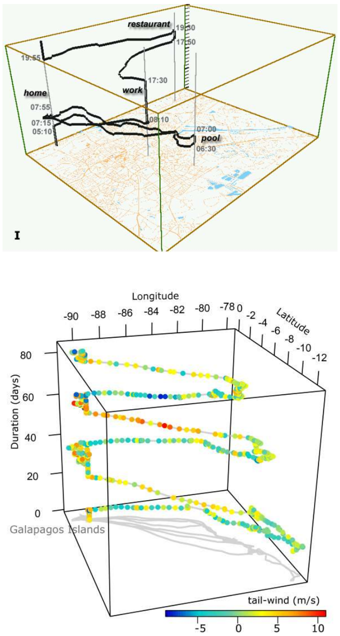

Figure 1: Different examples of space-time visualizations [2].

This article presents a different approach to spatio-temporal dataset exploration by combining the inherent utility of tangible objects [5][9] to represent entities in a set of spatio-temporal data with the opportunity to enrich the information they represent in space and time by using embedded visualizations [10]. By doing so, we are developing an agenda that will push the boundaries of what is possible with tangible user interfaces for data exploration and interaction.

Approach

As is common, most approaches in human-machine interfaces are iterative and build on several design-implementation-evaluation steps, allowing a continuous refinement of the initial project conception, while eliminating technical assumptions and validating empirically the various concepts involved.

First, we propose to represent objects using physical entities such as Zooid mini-robots [5] or Ozobots [8], or even the Cellulo robots [7] that can provide additional haptic feedback. They are dynamic, can move along predefined trajectories and represent the tangible element of our dataset exploration. Each robot representing an object can be touched, held and probed to facilitate quick data exploration. Because of their autonomous behavior, they are able to adapt to physical interaction from the user or to the reception of new digital inputs that offer additional information.

Secondly, we propose to represent the spatial element through a tabletop display at first, and finally with visual displays superimposed on our tangible bots (via augmented reality). The mini-robots will be able to move freely on the tabletop display indicating their spatial extent and locations, as illustrated in Figure 2. Tabletop

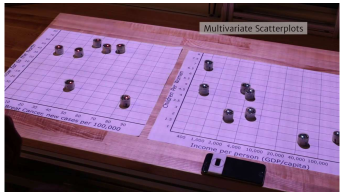

Figure 2: Use of tangible robots to visualize simple data [5].

displays are an intermediate physical support to mini-robot movement, but they are also interactive. The operators can request more information directly on the table, as if they interacted with their own laptop. Finally, the temporal dimension is represented by the movement of the mini-robots in place.

An often overlooked aspect of visual analysis is the need for a personal "scratch pad" [6]. In addition to the spatio-temporal information provided by the mini-bots moving on the interactive table, we propose to add personalized visual information associated with each of the bots to add or merge the spatio-temporal data communicated by the tabletop displays and the movement of mini-robots. This will then greatly facilitate the visualization of data and their variation based on physical interactions or the reception of new data.

Use case

An ideal case of using such a platform could be the following scenario. A group of scientists have assembled to mitigate what is considered to be one of the deadliest and fasting spread of an epidemic. They need to contain the disease. Assembled around a digital table in a control room, they have objects they can hold, and that move around the table, each representing an entity they suspect as being a carrier of the disease. As the pieces move autonomously or as a scientist picks a piece and moves it to a location, the underlying spatio-temporal data gathered from surveillance cameras or sensors, shows the reciprocal movement of all the other agents or objects. This quickly gives them clues about the displacement of such entities, their locations, the speed at which they travel, and their future movement direction. Through multiple interactions, the scientists quickly ascertain which agents are moving the most, the ones that cover vast distances as well as those that have the most interactions with other agents. They quickly make a decision about which individuals to quarantine and the disease is soon under control.

Given the widespread movement of individuals, the multitude of daily interactions and the complexities inherent in these, we cannot resort to mouse and computer solutions, any longer. These do not allow for the exploration of data groups, they limit the visualization for the information to a display and offer minimal interactivity. Instead, we propose to develop a platform composed of tangible moving objects, with representations of their interactions on the digital tabletop, such that group can interact and dissect with vast repositories of data. Such a development will be matched with equal effort to advance our knowledge for how tangibles and augmented displays can be used for displaying, interacting and analyzing complex data.

Conclusion

A system that simultaneously employs tangible and visual interaction to access, interpret, and manipulate spatio-temporal datasets can offer novel interaction methods. Mobile mini-bots on a tabletop display, that an analyst can physically manipulate (grasp, hold, displace) allows direct interaction with complex spatio-temporal data, a service that other classical tools cannot provide. Furthermore, personalized data visualization displayed above each robot will greatly reduce the workload and will allow each user to consult the adapted data to its profile. As such, the system will provide a better understanding of complex data for each operator, but also for the team working in collaboration. In addition, the interactive table will enhance teamwork while allowing physical support for the movements of mini-bots and tracking their trajectory. We are embarking on a project to implement this method for complex data visualization and manipulation by focusing on the consistency between the behavior of the mini-robot swarm, the tabletop displays and the additional visual information displayed above the physical entities using augmented reality. This will provide us an environment to examine a multitude of hypotheses.

Acknowledgements

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