Interactive Visual Analysis of Animal Trajectories in a T-Maze

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Abstract

Research of animal behavior helps scientists to better understand different behavioral processes of animals and humans. The T-Maze is used to study the learning ability. Trajectories resulting from conducted runs in T-Maze are evaluated. Current state of the art methods analyze trajectories of individual animals separately, and then use only scalar features in the ensemble analysis. Interactive visual analysis can be used to improve the analysis of ensembles of trajectories and their features. In this paper, we introduce the *Gate-O-Gon*, developed to solve domain experts' tasks. The *Gate-O-Gon* is a specific visualization for T-Maze data showing overall direction characteristics of animals and it is integrated in a coordinated multiple views system. This paper presents the *Gate-O-Gon*, the integrated system, and analysis tasks which were identified by domain experts in related work.

Keywords: Interactive Visual Analysis, Animal Trajectories, Coordinated Multiple Views, Memory Learning

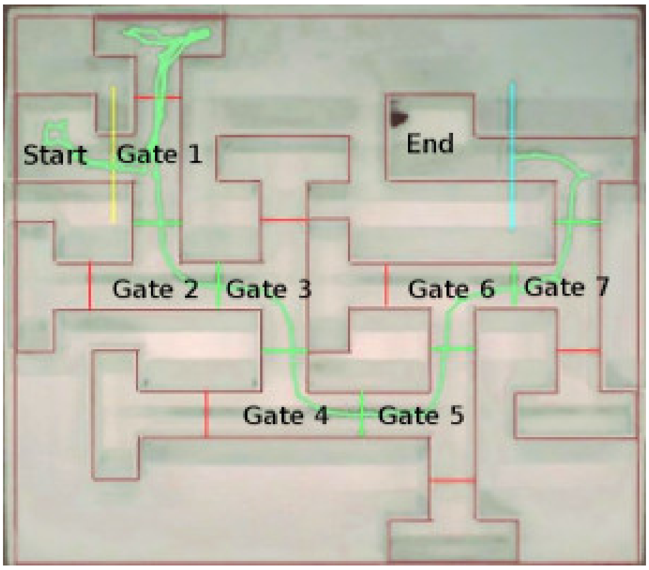

Figure 1: A picture of the T-Maze experiment showing the 7 T-segments, the start and the end area. The mouse is sitting in the end area after it successfully completed the task, the corresponding trajectory is also depicted.

1 Introduction

To get a deeper understanding of the complex human being, its physiological processes, and eventually to develop better medical care, animal behavioral studies are often used. These studies enable research on neural mechanisms, underlying learning processes, or physiological processes, which can be very similar to those of humans [3]. One experiment commonly used in behavioral studies — used primarily on rodents — is the T-Maze. The T-Maze is a simple maze consisting of T-shaped segments with one right and one wrong path. By observing and tracking the rodents in the maze, researchers get insight on working memory and spatial learning. This enables a deeper insight on the animals' learning ability.

The T-Maze used in the experiments which are described in this paper consists of seven T-segments as shown in Figure 1. The animals are placed in the start area and recorded with a video tracking system until they reach the end area or time runs out.

The state of the art analysis commonly interprets the rodents' trajectories separately, the analyzed results provide no information about the whole ensemble of trajectories. The analysis is based on scalar features of trajectories (such as length, average velocity, or time needed to reach the end area). Previous work has shown how interactive visual analysis can help in comprehending trajectory ensembles, originating from an open field experiment [5]. After domain experts gave positive feedback and motivation to continue the research, we extended it to the T-Maze data. The *Gate-O-Gon* is the first visual result motivated by specific tasks in the T-Maze experiments.

2 Interactive Visual Analysis and related work

Visual Analytics [4] is the science of analytical reasoning facilitated by visual interactive interfaces [8] . Interactive Visual Analysis gives insight on not apparent information contained in data. By interacting with the data and getting a prompt visual feedback new and different information

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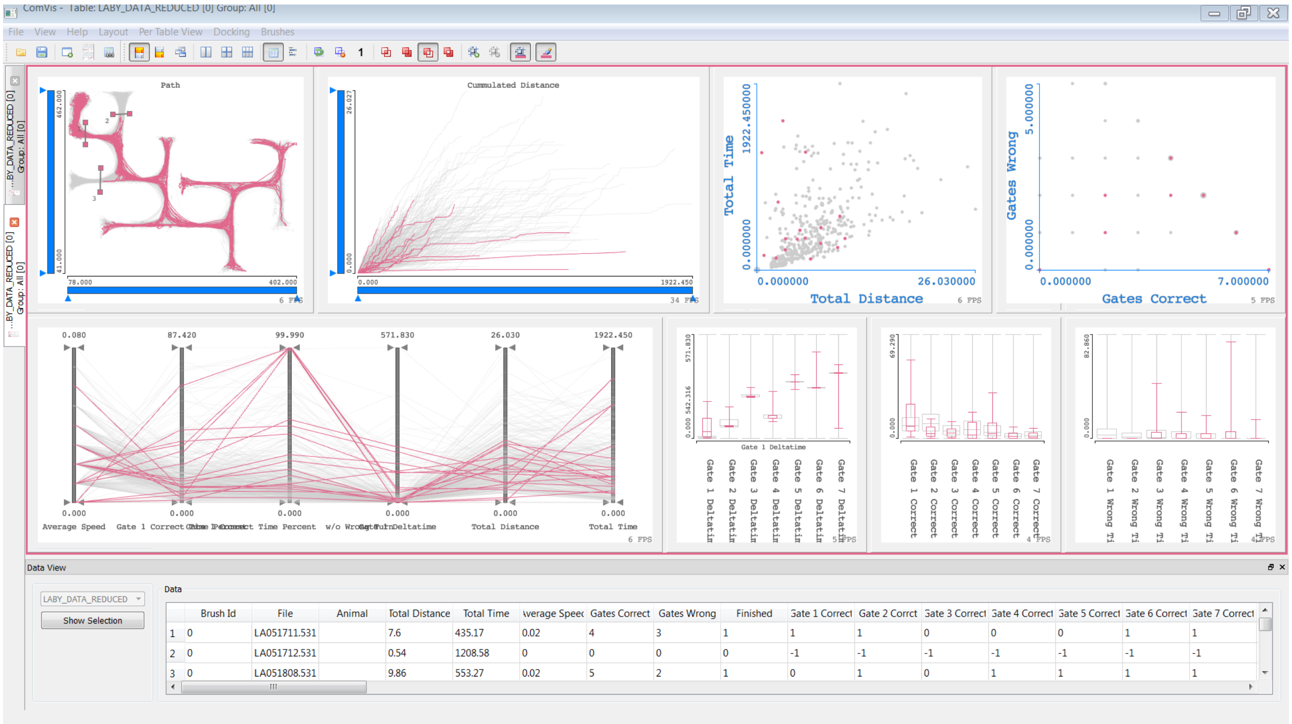

Figure 2: A screen capture of an analysis session using currently available views in the Coordinated Multiple View System 'ComVis'. Each view represents the whole ensemble of animal trajectories and gives different insight on it. Views such as'Curve view', 'Box Plot', 'Parallel Coordinates' or 'Scatter Plot' are used.

can be obtained. Interactive Visual Analysis often relies on the well known mechanism of coordinated multiple views (CMV) [6, 1]. The coordinated multiple views display various attributes or dimensions of a data set by employing different views simultaneously. The views are linked, and user can brush—interactively select a subset of data in any view. Brushing (selecting) a subset of data in one view highlights the same subset in all other views. The *Gate-O-Gon* is integrated in the CMV-System *ComVis* (Figure 2) which supports composite iterative brushing, as well as an advanced data model which allows, in addition to scalar values, time series and trajectories as atomic units, i.e., attributes in a record. Andrienko et al. [2] describe visual analysis of movement data combining interactive visual displays, cognition, and reasoning with database operations and computational methods.

3 T-Maze Ensemble Data and Analysis Tasks

The T-Maze used for the underlying experiments measures 1.4×1.4 meters. It consists of seven T-Segments (gates), the start area, and the end area. A gate consists of a corridor splitting into two visually indistinguishable corridors, one leading to the next gate, the other in a dead end. The experiment was conducted for two weeks, the first week focusing on the animals' short term memory, and the second week on their long term memory. In the first week the rats were put into the maze three times a day from Monday to Friday, in the second week only on Friday. The animals were motivated to run through the maze by giving them a reward (food placed in the end area). The runs were tracked with an infrared video camera in a dark room. Once an animal passed the correct path of the 7^{th} gate (which is equivalent to successfully completing the run) or the time limit expired the tracking ended.

Several questions arose after the trajectories are collected. Do the animals pass the correct gate first, do they turn back and run in the wrong direction, how far do they run back, how far did they come before making a wrong choice etc. In order to answer these questions, the trajectories are first evaluated and several scalar features are computed. The features include, for example, total time spent in each gate, total time and distance traveled, number of right and wrong choices etc. A gate is evaluated as correctly passed if the animal crossed the correct gate first, even if turning back immediately after. The times spent in each gate are computed separately for running towards the end (correct direction) and towards the start (wrong direction). The time an animal spends in the overall wrong direction starts after it correctly passed a gate. If it then starts running in the wrong direction (towards the start area) this gate is memorized until the animal passes a correct gate again. All times spent in the traversed gates in between yield the total time spent in the wrong direction. For ex-

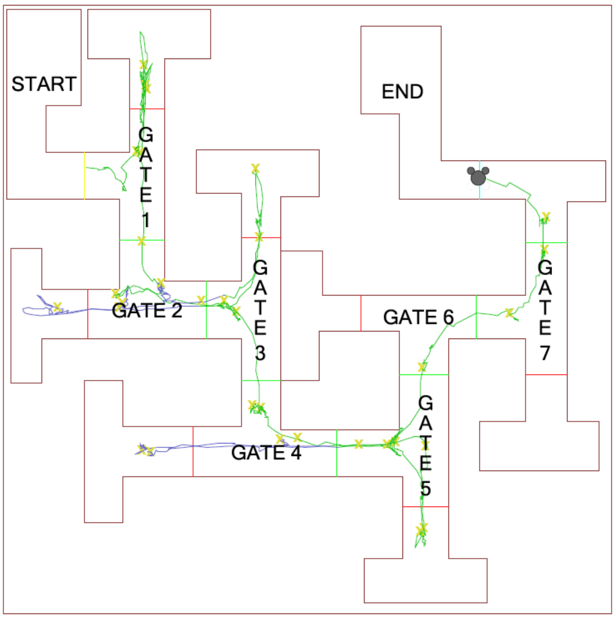

Figure 3: A screen capture of an analysis session using currently available views in the Coordinated Multiple View System 'ComVis'. The trajectorie is displayed in green, with the sections where the mouse runs in the wrong directions in blue. The Yellow crosses are an indicator of time, marking the position of the mouse every 5 seconds.

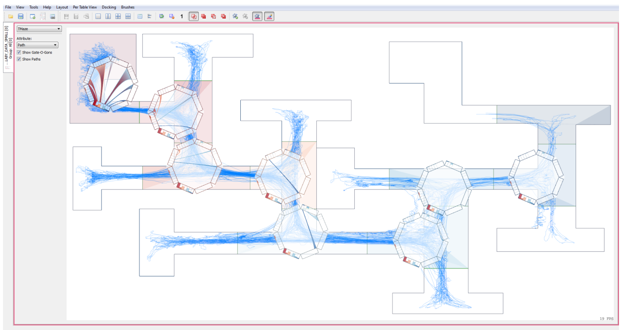

Figure 4: A screen capture of an analysis session using the Gate-O-Gon View. The T-Maze is visible in the back, each gate has a Gate-O-Gon depicting the distribution of time spent in the wrong direction for the respective gate.

ample, Figure 3 shows a trajectory partly green and purple. Green indicates the path running towards the end area, purple the wrong direction. Here the purple part show that the animal correctly passed gate five and returned to the start area. Here all times the animal spent in the gates four, three, two, one, and in the start area are computed.

Interactive Visual Analysis can help in answering the above questions by offering new possibilities to explore the whole trajectory ensembles at once. The data set which we analyze consists of one trajectory per run, with a total of 400 trajectories. In addition to the trajectory, each record has scalar attributes such as: Animal ID, total time, total distance, number of gates passed correctly, number of gates not passed correctly, and many more. Finally, the record also has a time series attribute—the distance traveled as a function of time [7].

4 Design and Development of the Gate-O-Gon

The complex data set as introduced above, can be explored using the CMV-system as already shown for the open field data [5]. With this system, visualizing scalar values and interactively brushing and selecting subsets offers analysis possibilities which lead to better evaluation than conventional approaches. But there is still room for improvement. The system does not answer questions related to the overall direction of the animal, and times spent traveling in correct and wrong direction. These are specific questions for the T-Maze experiments. The next step is to visualize not only if an animal was heading into the wrong direction but also where it turned around and how far it had already come at any given time. How can the distances be compared, as there is a difference between an animal that came back to the start area from the gate 5 or from the gate 1. The solution is a new view which displays where an animal runs in the wrong way. Note that the animal can be running in the wrong way only in the start area and in the gates 1 to 6. The gate 7 is irrelevant as the experiment stops as the animal enter the end area, therefore the animal can never be in the area of the gate 7 while moving in the wrong direction.

Let n_i be the gates whereas $i \in \{0,1,2,\ldots,8\}$, and $i = 0$ and $i = 8$ for the Start and the End Area. The maximum reached gate is defined as $R \in \{1,2,\ldots,7\}$. For each gate n_i where an animal is moving in the wrong direction we can identify R. "We are interested in the distribution of R for each gate. Note that we know that animals entered gate n_i from gate n_{i-1} or n_{i+1}, but we want to know how far the animal already had gone" [7].

The distribution of R is calculated from each trajectory. For this project the trajectories are already pre-evaluated and contain scalar values as well as the trajectory data. The trajectory data consists of coordinates. To compute the total distance traveled in the wrong direction each coordinate is evaluated separately. At any point of the evaluation the highest reached gate and the lowest retraced gate are known. Each coordinate is tested on it's position in the maze and assigned to the corresponding gate. Therefore the current direction the animal is running is known and whenever it changes directions to running the correct way, after retracing once, the total distance traveled in the wrong direction is known and saved in a distinct data-structure.

We propose a novel visualization of wrong direction distribution in respect to the gates. The newly introduced *Gate-O-Gon* depicts the wrong direction and the distribu-

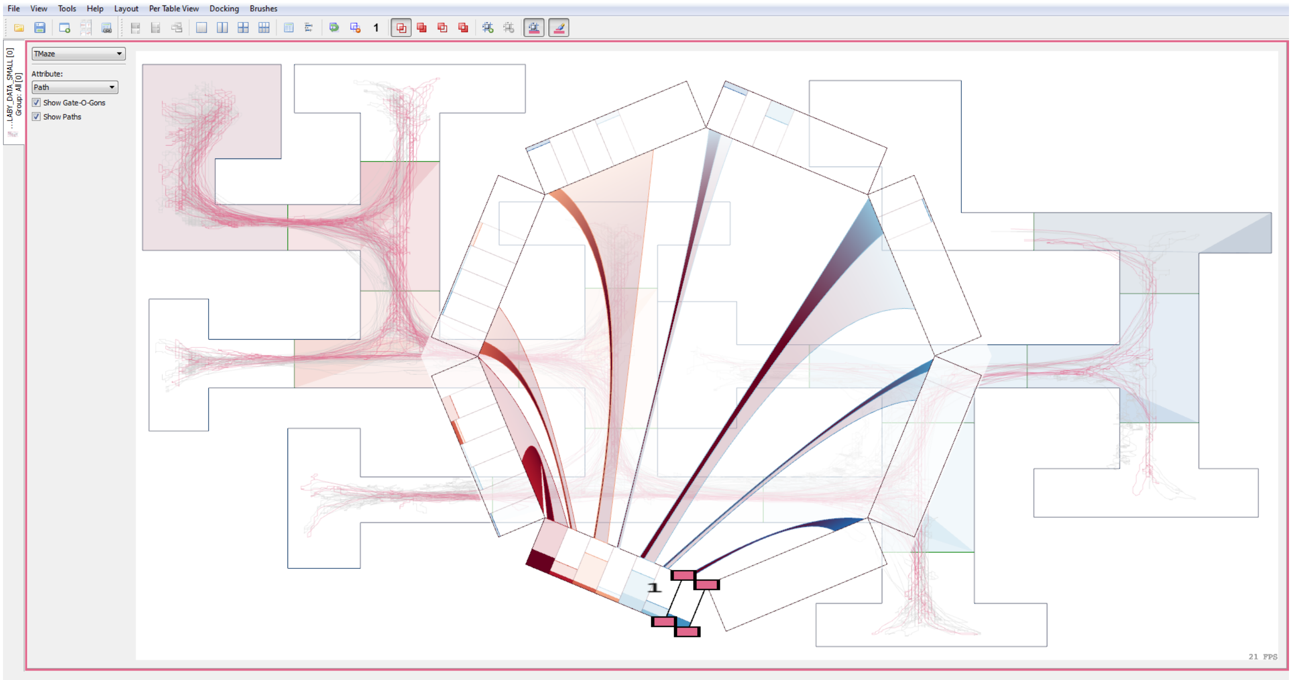

Figure 5: This screen capture shows an analysis session using the Gate-O-Gon view. The detailed view of the start area is selected. In this case a subset was selected as visible from the quadrangle in the histogram area. The subset contains all trajectories where the animal had passed the correct gate line of gate 7 but returned to the start area shortly after.

tion of R. It can be superimposed in the T-Maze itself. The set of trajectories can also be shown. As each gate has its own distribution, the *Gate-O-Gon* is placed on each gate. Figure 4 shows the current version of the *Gate-O-Gon* view. It gives a good overview of all wrong direction distributions, but is too small to get detailed information, hence a detailed view showing only the distribution of the selected gate, as shown in Figure 5, is also available.

The *Gate-O-Gon* (as depicted in Figure 5) is shaped like an octagon, each side representing a gate. The idea to use an octagonal shape was born from the wish to visualize a direct connection between two gates and that for all gates. The gates starting with the start area (gate 0) in the bottom left, followed by gate 1, 2,..., 6 are shown in a clockwise order.

The edges of the octagon also show the distribution of R of all gates as a histogram, with the selected gate highlighted and the others faded. At gate 0 the values of R can go from 1 to 7, at gate 1 from 2 to 7 etc. At gate n_i the values of R can go from $i+1$ to 7.

Additionally, the gate edges are connected by a strap also representing the distribution of R. At present the only distribution of the total times an animal was running in the wrong direction from gate n_j to gate n_i with $j > i$ is computed. Future design might contain other parameters such as correct time. For the selected gate i only connecting straps to gates $i+1$ are available, since, as mentioned before, an animal cannot run in the wrong direction when coming from a lower gate h to gate i, with $h < i$. The thickness of the strap reflects the distribution of R and it shows the same value as the histogram in the gate edges.

For easier distinction, each gate has a different color, blending from deep red to deep blue. For example, gate 0 is deep red, gate 4 is light blue and gate 7 is depicted in deep blue. The colors are reflected in the connecting strap and histogram, as well as in the T-Maze itself, where each gate is softly colored in the equivalent color(Figure 5). To emphasize the return direction from a higher gate connecting straps color is blending from the color of gate n_j to the color of the selected gate n_i. For example, in Figure 5 the connecting strap from the gate 5 to the gate 0 is blending from blue to deep red. These colors are also used to paint the background of the corresponding gates in the background of the MCV.

When selecting a subset of the data in a different view the *Gate-O-Gon* changes transparency, highlighting the brushed data set. At present brushing in the *Gate-O-Gon* is only possible in the detail view's histogram. Figure 5 shows brushing in the *Gate-O-Gon* histogram, returning animals from gate 7 to the start area are selected. The brushed subset is highlighted in the connecting straps as well as in the histogram. The whole ensemble set is hinted at by reduced opacity.

In the background of the *Gate-O-Gon*-View the used T-Maze is displayed. Inside the T-Maze the trajectories of the data set can be seen, using standard coloring of the ComVis MCV. Blue represents the whole, unbrushed data set, grey the non-selected subset, pink the selected subset.

5 Conclusions

This paper describes an idea for improving the analysis of animal trajectories ensembles. It introduces the *Gate-O-Gon*, a novel visualization which supports exploration and analysis of many trajectories at once. We will evaluate if the Gate-O-Gon can give answers to the important question of animal direction in particular gates and the previously achieved furthest point in case of the wrong direction.

Further improvement steps could include further development of the *Gate-O-Gon*, different approaches to display the distribution of the total traveled distance, or a heat map. We, moreover, plan a close cooperation with domain experts and conduct a comprehensive evaluation.

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