Target Tracking in Dynamic Systems

Nivedita R. Kadaba[1]
University of Manitoba
Department of Computer Science

Pourang P. Irani[2]
University of Manitoba
Department of Computer Science

1. INTRODUCTION

A significant amount of information used in the information sciences can be represented using dynamic simulations and animations. While the debate on how and whether animation can be applied effectively has not been resolved [6], many environments necessitate visualizations that are updated dynamically. This includes the display of air traffic control systems, video games, natural phenomenon, etc. In addition researchers in information visualization are exploring the nature of animations in depicting abstract concepts that change over time such as in software engineering and programming, in tutoring systems, and in assembly instructions. As a result, the effectiveness of these systems depends upon techniques that facilitate viewing visual information that is dynamically being updated.

Studies have noted that along with displaying information visually, it is also important that the users exercise a certain degree of control over the visualization, so as to identify sections of the display that are more important than the others. This is especially true in dynamic systems where many changes occur to systems simultaneously, and unless focused upon, important and minute concepts can be easily misunderstood.

Figure 1: Screenshot from "Age of Mythology" by Microsoft and Ensemble studios.

In addition, tracking objects becomes complicated as multiple events are occurring simultaneously. For example, Figure 1 displays a screenshot of a popular game created by Microsoft and Ensemble studios. In this game, the user assumes the form of one of the game characters and fights against several enemies. However, without any external aids, game players can find difficulty in focusing upon crucial characters in the scene, which could eventually cost them the game. While in gaming situations the challenge is necessary for enjoying the game, radar controllers for example have to be concerned with changes that occur simultaneously in the display. Therefore developing techniques to improve tracking multiple moving objects or targets can assist users. In order to isolate the targets from the distractors in a cluttered scene, focus and attention techniques need to be employed and given priority.

Several studies have analyzed techniques for improving feedback and attention in dynamic systems. Techniques such as Digistrips [4] evaluated the importance of object tracking in air traffic control. Air traffic is monitored by controllers who are designated with various sections of the air space. The responsibility of the controller is to monitor all flights entering, leaving, or traveling within his/her jurisdiction, avoiding any collisions. Digistrips uses visual cues such as animation, vibration, flickering, color, texture, and transparency to display information and to capture and direct users' attention to important events in the display. Though such techniques mostly display auxiliary information and do not truly visualize dynamic motion, they form a strong basis for further study of visual displays.

The human visual system has a very limited capacity of keeping track of multiple objects that are displayed dynamically. Studies [1, 7] have shown that even with training and expertise, human capability of tracking multiple objects is quite minimal. These studies state that on average, participants could track up to a maximum of 6 objects simultaneously. These studies also suggest that an increase in the number of objects and/or distractors reduces the object tracking capability considerably [1, 7]. However, several other studies [5] have shown that object tracking can be considerably improved by providing visual cues such as feedback that draws users' attention to crucial events in a scene.

One of the more recent methods of providing feedback and drawing attention has been through the use of semantic depth of field (SDOF) techniques. SDOF techniques employ the use of the 3-dimensional properties of visual displays. In this technique, all objects are assumed to be located in a 3-dimensional space. Objects that are considered distractors are placed at a further distance from the eye, compared to the targets. This focuses the users' attention on objects that are closer to the eye (targets) than on the objects that are further away (distractors). This spatial effect in SDOF is achieved through the use of dimming techniques, i.e. the targets retain their normal clarity, while the distractors are blurred or dimmed out. Studies [2, 3] have shown that participants were able to intuitively detect targets among distractors and did perform better with SDOF than without them.

We postulate that SDOF techniques can be adapted to facilitate focus, in tracking multiple moving targets. In radar tracking, air traffic controllers could use this method to view the planes in their air space (targets), while viewing the aircrafts in the rest of the airspace (distractors) in the background. The study described here investigates the effectiveness of the SDOF method in improving focus and attention in dynamic scenarios. Also, to analyze the effectiveness of this method over other visual focus and attention techniques, our study compares SDOF with a simple highlighting technique such as the use of arrows.

2. EXPERIMENT DESIGN

The experiment consisted of tracking objects displayed on the screen. Two groups of objects were shown; large number of objects (Number (N) = 30) and small number of objects (N = 15). All of the objects were of the same shape (Edges (E) =4)

[1] nrkadaba@cs.umanitoba.ca
[2] irani@cs.umanitoba.ca

and color, with the size being varied randomly between the objects. Also, the initial spatial positions of the objects were randomly generated with no overlapping or occlusion.

20 undergraduate students from a local university participated in this experiment. Prior to the start of the experiment, the participants were given a description of the system along with a demonstration and practice trials of the concepts being tested.

The experimental simulation was as follows; initially a target space (chosen randomly) was flashed to the participants for 3 seconds. The target space varied randomly between: small (MIN =1 and MAX=3), medium (MIN = 4 and MAX = 6), and large (MIN = 7 and MAX = 9). The objects then commenced moving around the screen in random paths, with constant speed. After about 10 seconds, a randomly chosen subset of the target space changed size. Three display methods were compared in order to determine if SDOF can facilitate multiple target tracking: No Indication (NI), Semantic Depth of Field (SDOF), and a highlighting method using arrows to show the objects that were changing. In the NI method there was no indication during the course of the simulation of the occurrence of change. In the SDOF method, all the distractors were dimmed out while the target space objects were untouched. In the arrow method, the target space objects were highlighted by pointed arrows, while the distractors were unchanged (Figure 2).

(a) (b)

Figure 2: Screenshots of the SDOF and Arrow techniques displayed in the experiment.

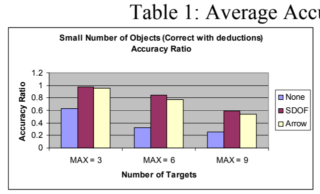
The main task of the participants was to view the target space that was flashed to them at the beginning of the simulation, keep track of the target space objects as they moved about the screen, and determine which of the target space objects changed size during the simulation. The participants were asked to hit a key to notify us as soon as they have an answer ready. They were then required to manually click on the targets that they saw changing during the experiment. The participants were also warned beforehand that there could be some objects, not belonging to the target space, that might change (distractors), and that these objects should be ignored as best possible.

The experiment was counterbalanced using a Latin square design and was manipulated based on three independent factors; number of objects (small/large), size of target space (small/medium/large), and type of semantic (NI/SDOF/arrow). All possible conditions of these three factors were tested (54 trials/participant). The participant was evaluated based on the number of correct answers (number of objects that they chose in the target space that actually changed during the simulation) and time taken (amount of time elapsed before they stopped the simulation to submit their answers). Preliminary results of the experiment have been described below.

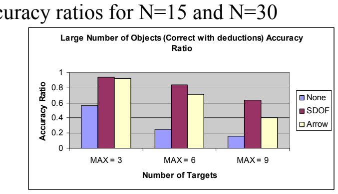
3. PRELIMINARY RESULTS AND DISCUSSION

A preliminary analysis was conducted on the experimental results. A straightforward grading scheme was chosen, where one point was awarded for each correct answer (participant correctly chose a target that changed during the simulation) and one point was deducted for each wrong answer (participant chose a target that did not change or did not choose a target that changed during the simulation). The results were averaged across the three trials for each combination and over the 20 participants. The average accuracy rates of chosing the correct targets have been displayed in Table 1.

Table 1: Average Accuracy ratios for N=15 and N=30



N=15



N=30

The results state that accuracy rates are affected considerably by the number of targets and distractors in the scene. With small number of objects, though the difference between NI and visual feedback techniques is significant, there is not much difference between the SDOF and arrow methods. This can be attributed to the fact that the number of objects in the screen might have been too small in number and hence could be tracked easily. This analysis can be validated in the accuracy rate for large number of objects. When the number of objects in the scene increases, significant improvement in object tracking is seen with the SDOF method over the arrow method.

4. CONCLUSION

Several studies have analyzed the importance of improving focus and attention in dynamic scenarios. A recently developed visualization technique referred to as Semantic Depth of Field uses blurring and/or dimming properties to facilitate pre-attentive processing. This work investigates the use of SDOF to improve focus and attention in dynamic visualizations. Preliminary results of our study state that as the number of objects in the scene increase the SDOF technique provides better focus to important parts of the scene when compared to the NI or highlighting methods such as arrows. Future directions in this work involve a thorough analysis of our experimental results, and evaluating its effect in dynamic applications such as video games and air traffic control systems.

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