Supporting Spatial Awareness in Training on a Telemanipulator in Space

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Abstract. In this paper, we present an approach for supporting spatial awareness in an intelligent tutoring system, the purpose of which is to train astronauts to operating tasks of a telemanipulator. Our aim is to propose recommendations regarding knowledge structures and cognitive strategies relevant in this context. The spatial awareness is supported through efficient use of animations presenting different tasks.

1 Introduction

The capabilities of spatial representation and reasoning required by the operation of a remote manipulator, such as Canadarm II on the International Space Station (ISS) or other remotely operated devices, are often compared to those required by the operation of a sophisticated crane. In the case of a remote manipulator, however, the manipulator has several joints to control and there can be several operating modes based on distinct frames of reference. Furthermore, and most importantly, the task is remotely executed and controlled on the basis of feedback from video cameras. The operator must not only know how to operate the arm, avoiding singularities and dead ends, but he must also choose and orient the cameras so as to execute its task in the safest and most efficient manner. Computer 3D animation provides an complementary tool for increasing the safety of operations.

The goal of training on operating a telemanipulator like Canadarm II is notably to improve the situation awareness (Currie & Peacock, 2002) and the spatial awareness (Wickens 2002) of astronauts. Distance evaluation, orientation and navigation are basic dimensions of spatial awareness. Two key limits of traditional ITS in this respect are cognitive *tunnelling*, i.e. the fact that observers tend to focus attention on information from specific areas of a display to the exclusion of information presented outside of these highly attended areas, and the difficulty to integrate different camera views. Our challenge is to produce animations (as learning resources) that are efficient in restoring spatial awareness, i.e. in improving the distance estimation, the orientation and the navigation. A training environment based on the use of automatically generated animations offers a natural integration of different camera views that represents a spatial and temporal continuity. Pedagogically, the use of such animations is justified by the fact that astronauts who look alternatively at different displays are compelled to achieve such an integration of different camera views.

To examine the learning of these three tasks, we have developed a 3D environment (figure 1) reproducing different configurations of the International Space Station and Canadarm II. This environment includes a simulator enabling the manipulation of Canadarm II robot manipulator, different viewpoints and camera functionalities, as well as an automated movie production module.

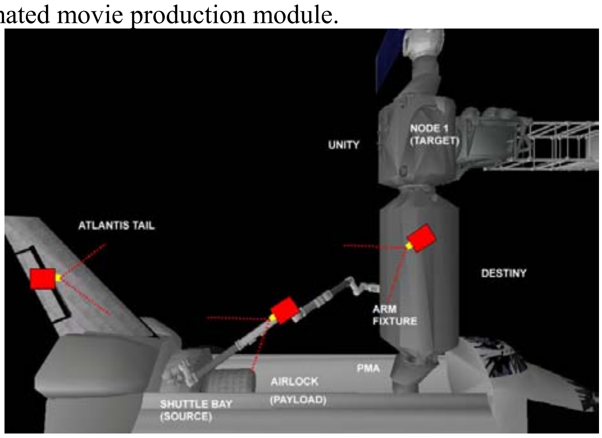

Figure 1. A screen shot of the working environment.

2 A model for automatic production of pedagogic movies

Movies used in our learning environment are pedagogic resources which can be generated automatically depending on formal task specifications. In order to make such an automated generation possible and to reason about the movie structure, cognitive task and navigation constraints, we use a graph-based movie model (Berendt, 1999) called *FILM route graph*. This graph combines properties of a film tree and a basic route graph, using concepts from cognitive modelling and computer graphics.

A film tree is a tree describing a film partitioned into sequences, scenes and frames; the partitioning may be based on the type or theme of activity in each sequence or the episodes in the movie. The basic route graph allows the reproduction of the process of distance inference between two landmarks. Typically, it models the capacity to memorise and process information used in distance evaluation. In the perception of distances covered, it is assumed that subjects have already covered a route and they are therefore requested to memorise the distances between the landmarks. The model is therefore useful inasmuch as the goal is to bring astronauts to learn a certain route.

The integration of the basic route graph into the broader structure of a film tree creates two challenges. First, the basic route graph has been validated in a virtual environment which proposes an egocentric camera viewpoint. It is therefore necessary to verify through experiment, whether the conclusions applicable in such an environment can be transposed into an exocentric shot. Secondly, it is important to clarify which cognitive mechanisms play a part in the interpretation of successive shots according to cinematic heuristics, in particular the integration of egocentric and exocentric viewpoints. This requires an experimental clarification.

3 The experiment and the lessons learned

Our experiment aimed at clarifying the extent to which the integration of viewpoints with cinematic heuristic rules does facilitate the integration of different viewpoints. It must validate the three following hypotheses: 1) cognitive rules can be associated to cinematographic rules; 2) the cognitive model for the evaluation of travelled distances can be adapted to the case of a representation based on several camera shots; 3) the main distortions in the evaluation of travelled distances are caused less by 3D perception problems than by problems linked to the films composition.

3.1 The main conclusions of the experiment

The experiment lasted about one hour. A total number of 16 participants took part in the experiment. They were distributed into three groups corresponding to three experimental conditions defined according to the movies shown to participants.

Three conclusion could be drawn from the results of experiments on the subjective evaluation of distances: 1) the viewpoint of the egocentric camera makes distance evaluation more difficult and even contributes to the distortion in the evaluation of distance travelled; 2) the omission of the presentation on the screen of a stretch of movement is likely to distort the evaluation of distance travelled, even if the subjects have additional information such as maps and pictures enabling them to infer a movement that is not observed; 3) the magnitude of distortions observed in distance evaluation seems to confirm that in the use of movies for learning, cinematographic distortions are more important than effects related to such factors as 3D perception.

3.2 Learner's model and cognitive strategies

The FILM route graph provides a model which is quite appropriate for orienting learning, since it values the analysis of encoding mechanisms which allow a better retrieval of information from the long term memory. Also, the proposed representation does not include any additional assistant device for distances and orientation evaluation. The graph helps in the formulation of display specifications (colours, shapes, etc) used for the identification of natural landmarks as well specifications for camera shots used to achieve a cinematographic representation that allows a better application of the model.

The results analysis of our experiment clearly shows different cognitive strategies used for space navigation. The main cognitive strategy is the evaluation of covered distance according to the size of an object. A second strategy used in the evaluation of distances covered is the distance evaluation according to an assessment of movement speed and duration. A third strategy resides directly on the study of maps.

References

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