Navigation Assistance for Wayfinding in the Virtual Environments: Taxonomy and a Survey

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Abstract

Efficient Navigation is essential for the user-acceptance of the Virtual Environments (VEs), but it is also inherently, a difficult task to perform. Resulting research in the area provides users with great variety of navigation assistance in VEs however it is still known to be inadequate, complex and suffers through many limitations. In this paper we discuss the task of navigation in the virtual environments and record the wayfinding assistance currently available for the VEs. The paper introduces taxonomy of navigation and categorizes the aids on basis of the functions performed. The paper provides views on current work performed in the area of non-speech auditory aids. Further we conclude by providing views on the important areas that require further investigation and research.

1. Introduction

Virtual Reality technology has been used in wide-ranging fields including Flight Simulation, Architecture, Medicine, Scientific Visualization as well as Entertainment. The prominence of VR in various application domains initiated a growing need among the community to overcome the drawbacks of the technology. Consequently one of the research areas focuses on devising techniques and aids for efficient navigation in virtual environments.

Navigation is considered a crucial aspect for defining usability, effectiveness and performance of/in a virtual environment [6, 7]. Problems related to navigation have been encountered in many VEs and they manifest themselves in several ways. User faces problems such as disorientation, loss of overview, difficulty relocating previously visited locations or finding an object traced earlier have been witnessed and consequently has caused frustration, user discontent and discontinued use of the Virtual Environment [4, 6, 7, 11]. Even though many benefits have been claimed for employing the Virtual environments instead of real world, drawbacks such as navigation errors in VEs can easily make the experience as demanding and complicated.

Number of solutions has been proposed in form of guidelines, techniques, algorithms, strategies and aids, each possessing different advantages as well as drawbacks. This paper concentrates on navigation aids developed to assist the wayfinding process. It provides a brief introduction to navigation and related principles acquired from important research performed on navigation. Further more, it provides an account of current available navigation aid and describes the state of current auditory aids, its benefits and limitations. Views on future directions and areas requiring further research are presented.

2. Navigation

Researchers have long argued that navigation principles from real world are applicable and prove useful for achieving efficient navigation in virtual worlds [6, 7, 19]. One of the definitions describes navigation as the process by which people control their movement using environmental cues and artificial aids such as maps so that they can achieve their goals without getting lost [7]. Navigation in totality is a combination of: Way finding and Travel [19]. Wayfinding is defined as the process of determining and following a 'path' or 'route' between an origin and a destination [1]. Way finding is a purposive, directed and motivated activity and can be observed as a trace of sensorimotor actions through an environment. Way finding is also defined as the process of determining the strategy, direction and course needed to reach a desired destination [37].

Further studies related to wayfinding have proposed the importance of spatial knowledge and navigational awareness to be significant for the process. Navigational Awareness is defined as having complete navigational knowledge of an environment. Spatial Knowledge helps a user to construct a cognitive map which is required for skillful wayfinding and navigating with confidence in real and virtual world. A cognitive map is an internal representation of an environment gained by a comprehensive set of observations, and is used to travel between locations in the environment. Researchers believe that this map-like representation of environment has picture –like qualities and conceptualizes the space from

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general to specific in a mental hierarchy. Human beings try to make the environment mentally manageable by dividing it into logical units that form a hierarchical structure.

Downs and Stea, proposed that wayfinding is done in four steps [19]:
1. Orientation: Determining where one is in respect to nearby objects and the target location.
2. Route Decision: Choosing a route that will get one to their destination.
3. Route Monitoring: Monitoring the route one has taken to confirm that one is on the correct route and is going in the right direction.
4. Destination Recognition: Recognizing that one has reached the correct destination, or at least a point nearby.

Orientation infers that some landmarks must have been distinguished and selected by the navigator. The navigator knows what the landmarks are, where they are, and their relative position in relation to their own location. We use this model of wayfinding in this paper to classify the navigation aids and study related research for each wayfinding.

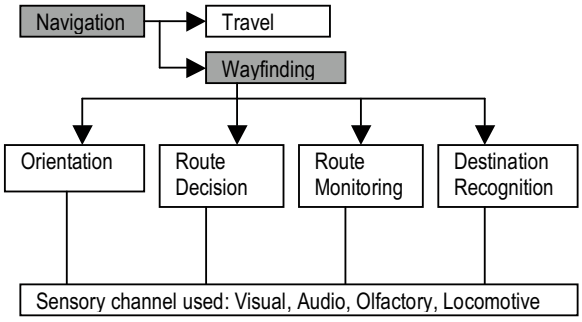

Figure 1: Taxonomy of Navigation

2.1. Need for Navigation Support

Navigation is an integral part of all Virtual Environments from desktop VEs to large-scale immersive VEs, and as the size of VE grows navigation becomes even more challenging.

Virtual Environments are able present with interactive three-dimensional spaces, and they are considered important means for training and transfer, assessment and examination of spatial knowledge and spatial abilities. Analogous to its real-world counterparts, representation of accurate spatial knowledge by the VE is thus important for effective navigation and successful accomplishment of task goal. However, on the contrary, in terms of navigation, VEs have come short to its predicted performance. VEs are abound of navigation problems such as difficulty finding places during exploration, experience slower acquisition of spatial knowledge and difficulty developing configuration knowledge of the VEs compared to their real world counterparts. [4, 11] Also other problems may be expected due to several reasons such, the computation and hardware limitations virtual environment provides less sensory cues or detail (visual, auditory, locomotive) such as landmark objects, distance, depth, direction, and motion, resulting in less descriptive spatial information. Usually wayfinding performance decreases as an environments complexity increases, which is why navigation problems become even more critical in large-scale VEs. Users are usually forced to navigate extensively integrating information derived from different perspectives which adds to the complexity.

Since navigation in VEs is significant process, much effort has been put into research and development of navigation assistance in form of navigation aids. Navigation aids assists the user to gain spatial knowledge about the environment which is of utmost importance for the users performance in a way finding task. Many studies have shown that navigational performance is much better with assistance of navigational aids then without any assistance.

2.2. Navigation Aids: Assistance in Virtual Environments

Navigation in virtual environments constitutes of four elements - Way finding (***W***), Travel (***T***), User (***U***) and Virtual Environment itself (***V***) [hardware and software].
$\boldsymbol{N} = \{\boldsymbol{W}, \boldsymbol{T}, \boldsymbol{U}, \boldsymbol{V}\}$

Elements of Navigation in VE are highly interdependent on each other either directly or indirectly in order to perform optimally, and the navigation performance as a whole is the function of performance each element.

Navigation assistance in VEs consists of two main areas of research – The first area of research is concerned with the ***V*** and ***U*** elements of the process, which mainly concentrates on devising guidelines for designing navigable environment and factors that affects the navigation in these environments such as human behaviour and age and environment properties and organizationNavigation assistance in VEs consists of two main areas of research – The first area of research is concerned with the ***V*** and ***U*** elements of the process and the second area of research, which also is the concern of this paper, concentrates on providing users with assistance in form of electronic navigation aids for the ***W*** and ***T*** elements of the process and acts as a supplement to increase their learning and exploration capability. The aim

of navigation aid research is to prevent disorientation problems and to keep navigation as simple as possible, while preserving the elements of exploration and discovery [4].

Researchers have conducted various studies and proposed different kind of aids to assist wayfinding in VEs. Adhering to the classification of wayfinding steps provided Downs and Stea [19], the table below provides with information regarding various wayfinding assistance and steps (function) it serves to:

Aid	Orientation	Route-Decision	Route-monitoring	Destination Recognition
Visual Aids				
Textual Descriptions		√		√
2D Maps	√	√	√	√
Districting[12]		√	√	
Grid Navigation[11]	√	√	√	
Landmarks[1,22,41,9]	√	√	√	√
Coordinate Feedback [12]		√	√	
Location-pointing -2D/3D arrows [34]		√		
Radar metaphor [34]		√	√	
3D Maps [34]	√	√	√	√
WIM	√	√	√	√
Magic lens /Magic Mirror[19,36]		√	√	
Worldlets [15]		√		√
Trails		√	√	
River analogy [18]	√	√		√
Semi-transparency [38]			√	
Navigation by query [3]		√		
Intelligent Agents: Personal Agents, Embodied Agent[2, 18, 25]		√		
Interactive Spaital Cognitive Map [27]	√	√	√	
Auditory Aids				
Dialogue agents		√		
Audio, Acoustic Landmark[24, 43]	√	√		√
Music[10]		√	√	√

2.3. Non-Speech Auditory Navigation Aids

Various studies have been conducted for devising effectual auditory navigation techniques in VEs. Sound in form of speech as well as non-speech sound for navigation aid has already been studied by many researchers. Speech is more likely to be used for the purpose where the meaning of the auditory messages is obvious such as enquiry and announcement, satellite navigation systems for vehicles. Speech audio has been used to guide sighted as well non-sighted users however non-speech sounds are believed to be more beneficial for presentation of continuous data. Petrie et al mentioned on interfaces for visually impaired using speech [25] that “speech is potentially confusing, a relatively slow method to communicate information” and also use of non-speech sound is preferred in contrast to speech sounds due to minimal information load from the former. Moreover principles of human factors suggest the avoidance of speech channel when not absolutely necessary [22].

Early auditory navigation techniques that used musical sounds include the ear cons and auditory icons [21]. However these techniques are limited to two-dimensional environments. Non-speech sounds in form of beacon such as pure sine wave, sonar pulse, musical sounds etc, has been investigation for the purpose of navigation in VEs. Beacon sounds and its qualitative aspects have been further studied for localization [23, 24, 25]. Constabile and his colleagues [23] investigated the functional and aesthetic roles of music in VE navigation for faster identification of relevant areas in VE, allowing the users to progressively build a mental map of the environment. These musical sounds used for the purpose of navigation research mostly consisted of non-continuous musical sounds [22, 24].

3. Conclusion

Majority of navigation aids are still visually dominated and the use of audio for the purpose forms a fertile ground of research. Very little comparable research and development has been performed on usefulness of audio for navigation purposes in VEs, the available results suggests the use of audio especially non-speech sounds such as structured audio and music, form a promising

medium to serve as navigation aid in VEs consequently forming an important area of research.

4. Future Work

In contrast to previous auditory navigation aids for the VEs, we focus on devising navigation aid which makes use of *continuous* music to provide a *minimal attention* method to assist the wayfinding process in the VEs. that The approach uses music to convey the direction of routes to the navigator The main aim of the approach is to exploit the benefits of music which provides accuracy by exploiting the auditory localization ability of the user, be less cognitively demanding using auditory channel for minimal attention of the user for the task and improving the ambience of the environment owing to aesthetic quality of music, consequently improving the overall performance and experience of a user in virtual environment.

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