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Virtual prints: Augmenting virtual environments with interactive personal marks

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Abstract

This paper introduces the concept of Virtual Prints (ViPs) as an intuitive metaphor for supporting interaction and navigation, as well as a number of additional tasks in virtual environments (VEs). Three types of ViPs are described: Virtual Footprints, which are used for tracking user navigation (position, orientation and movement), Virtual Handprints, which are used for tracing user interaction with the VE, and Virtual Markers, which are 'special' marks (usually coupled with information) that can be created upon user request. In a VE, the ViPs concept is instantiated and supported through a software mechanism (the *ViPs mechanism*) that allows users to create, manage and interact with their personal ViPs, as well as other users' ViPs.

The paper presents the background and related work upon which the suggested concept builds, as well as the distinctive properties that differentiate ViPs from other related efforts. An account of how users can interact with ViPs is provided and related issues and challenges are discussed along with techniques and methods for addressing them. The paper also describes the process followed towards defining and experimenting with the concept of ViPs by means of iterative design and evaluation of an interactive prototype. This process involved exploratory studies, as well as several inspections and formal tests with both experts and potential end-users, in order to assess the usefulness of the concept and identify possible shortcomings, and also to evaluate and improve the usability of the proposed designs and software prototypes. In general, the findings of the studies reinforce the initial hypothesis that ViPs are an intuitive and powerful concept, and show that the related software is easy to learn and use. Overall, the results of the studies support strong evidence that an appropriately designed and implemented, fully functional ViPs mechanism can significantly increase the usability of VEs.

1. Introduction

In the real world, every living organism constantly leaves traces of its existence and its interaction with the physical environment: deer leave their paw marks on the soft forest soil, dolphins carve foam traces on the surface of the sea, flies leave annoying black spots on windows, and young children imprint their dirty handprints on freshly painted house walls.

Since the early years of their presence on earth, humans observed this inherent property of the environment and learned to use it in various ways in order to make their lives easier. For example they learned to recognize the paw prints of animals to track down their prey or to avoid ferocious creatures, they used footprints to explore unknown territories or find their colleagues in search and rescue operations (Kearney, 1999), they examined fossils to study human history and evolution (Tattersall, 1995), and they revealed and analysed fingerprints to solve crimes (Beavan, 2001).

In contrast to real environments, Virtual Environments (VEs) do not allow their 'inhabitants' to leave any trace behind, thus suffering from an '*extreme cleanness syndrome*'. Walk into your house after leaving your children alone for the weekend and you can instantly realize that a wild party took place while you were away. Walk into a virtual chat room seconds after a meeting of 200 people has finished and it will be exactly as if no one has ever been there before.

Inspired by these observations, the concept of Virtual Prints (ViPs) is proposed (Grammenos et al., 2002) as the digital, interactive counterparts of real-life tracks. The

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basic idea is that while a user is moving in a VE, Virtual Footprints (FootViPs) are left behind, whereas each time an interaction with an object occurs, the user's Virtual Handprints[1] (HandViPs) are 'imprinted' on it. Both FootViPs and HandViPs can be time-sensitive and gradually fade, as real—or virtual—time goes by. Virtual Markers[2] (MarkerViPs) are permanent marks coupled with user-defined data (e.g. a textual or audio message) which can be left in the environment, or 'pined' on any virtual object, and can act as personal landmarks, annotations or 'anchors'.

ViPs can have a variety of uses in a VE, ranging from supporting navigation (i.e. travel and wayfinding), to training and creation of tutorial sessions, conducting user-based evaluations, etc. Furthermore, as FootViPs and HandViPs are actually a means for recording and visualizing navigation and interaction history, respectively, they have the potential to introduce in VEs several functions and concepts that are popular, if not standard, in conventional 2D user interfaces, such as shortcuts, bookmarks, undo/redo functions, collaborative review, as well as marking/identifying (non) visited content (Mourouzis et al., 2003). Correspondingly, MarkerViPs can be used for content annotation and highlighting, or for offering context-sensitive help. Although this paper focuses on using ViPs in a VE, they can also be effectively used in Augmented Reality Environments. For example a person using an augmented reality system in a museum can follow ViPs that are related to a specific topic of interest, or those of a virtual guide.

A considerable advantage of ViPs is that they can be used in any VE and in combination with any existing navigation and wayfinding support approach. Furthermore, the fact that ViPs have real-life counterparts with which humans are very familiar renders them an intuitive and potentially easy to use metaphor.

The rest of the paper is structured as follows: Section 2 presents the background and related work upon which the suggested concept builds. Section 3 describes the distinctive properties and characteristics of each type of ViPs, while Section 4 provides an account of how ViPs can be instantiated in a VE through a related software mechanism, and of how end-users can interact with them. Section 5 illustrates challenges that may potentially arise when putting ViPs to real use, along with suggestions and ways for overcoming such challenges. Section 6 provides a comprehensive overview of possible uses of ViPs beyond navigation, orientation and wayfinding. Section 7 describes the process that was followed for making the transition from early concept formation to a full-functioning software implementation, including the exploratory studies which were conducted, as well as several inspections and formal experiments with both experts and potential end-users. Finally, Section 8 concludes the paper and offers an insight into future work.

[1]Virtual Handprints were originally named Virtual Fingerprints, but our studies revealed that the concept of Handprints is far better both in terms of usability and intuitiveness (e.g. fingerprints are too small to be noticed and to interact with).

[2]Virtual Markers were originally termed Virtual Fossils, but they were renamed as a result of user testing.

2. Background and related work

In the past few years, a number of industrial VE applications have been developed and put to practical use. The Virtual Reality (VR) market is growing rapidly (Arrington and Staples, 2000; CYBEREDGE, 2001) and VEs have been adopted as a useful and productive tool for a variety of applications (Delaney, 1999). Nevertheless, user feedback reveals that there are still several barriers that impede the sustainable and appropriate use of VEs in the industry environment, including barriers concerning the integration of technologies, barriers due to insufficient knowledge concerning the impact of such technologies on the user, as well as usability barriers (Crosier et al., 2000; Bowman et al., 2001).

2.1. Navigation in VEs

Navigation is a key task in any type of VE. Navigation can be considered as a combination of *travel* and *wayfinding*. Travel is the minimum interaction capability offered by any VE and involves the ability of the users to control the position (i.e. to move) and orientation (i.e. gaze direction) of their virtual body. Wayfinding means that the user is aware of his/her current location and of how they can to get to a desired destination. Although there have been numerous efforts in this area, navigation still remains a major challenge, since observations from numerous studies and usability analyses indicate that this task (especially in large-scale VEs) can be very difficult, and may result in user disorientation and distress (Ellis et al., 1991; Darken and Sibert, 1993; McGovern, 1993; Darken and Goerger, 1999; Vinson, 1999).

The reasons why navigation can be so cumbersome in VEs can be summarized in the following:

(a) *Navigation is a difficult task also in the real world.* Humans may have difficulties when dealing with unfamiliar or complicated and unstructured physical environments (e.g. a forest, a highway, or a modern building). To overcome these difficulties, navigation support tools have been developed including maps, compasses, signs, and electronic global positioning systems (GPS). Thus, even if VEs were indistinguishable from the real ones, navigation would still be a major challenge.

(b) *Lack of constraints* (Chen, 2003). In the real world, several constraints exist when moving from one location to another. There are paths to follow, doors to go through, insurmountable obstacles, and distance or time restrictions that significantly decrease movement possibilities. In most VEs, the user has the