Rethinking Temporospatiality in Everyday Virtual Environments

Ahmed E. Mostafa* Won Hyung A. Ryu† Sonny Chan§ Ehud Sharlin‡ Mario Costa Sousa¶
University of Calgary

ABSTRACT

While the design of entertainment systems and 3D games often incorporates time and space in a creative and flexible manner, space and time are often viewed in a more rigorous and limited approach when designing everyday virtual environments applications. The limited exploration of temporal and spatial aspects in the design of everyday virtual environments could limit user engagement and impact the overall experience. This paper aims to initiate a discussion about: (1) the challenges and needs associated with temporospatial design in everyday virtual reality contexts and (2) how proper utilization of space and time in the design of everyday virtual environments can enrich interaction and improve user experience. We introduce a set of temporospatial design elements that can be utilized to enrich interaction within 3D contexts, and show through illustrative examples how everyday contexts can benefit from temporospatial-inspired design.

Keywords: Spatial representation, time design, virtual environments.

1 INTRODUCTION

We live in a spatiotemporal world and interact daily with things around us in 3D space and over time. Arguably, we instinctively understand time and space together as seamlessly interwoven dimensions and much of our perception of time is informed by spatial metaphors [2].

Design of interactive systems involves practices of temporality that primarily aim at supporting efficiency (e.g., high performance systems with fast response time). Oftentimes, virtual environments (VEs) tend to include minimal support for temporal exploration and ignore the intimate relation between time and space. However, these environments represent spatially-rich contexts and can simulate processes that occurs in 3D space and over time. Thus, a rethinking that investigates temporal and spatial aspects in the design of interactive VE contexts is required, particularly within everyday (multi-user) contexts with their varying spaces and unique challenges.

A gamification experiential approach can be a starting point for our exploration, while focusing on enriching user experience within everyday virtual environment contexts. First, novel temporospatial elements should be identified by building on theories and inspirations from other fields. Then, validation and understanding of how temporospatial elements (e.g., trajectory, motion, etc.) have been successfully considered in other domains (e.g., games and film) and how such elements may be applied to enrich users' interaction within the 3D interactive virtual environment contexts. Based on the lessons learned, prototypes will be designed, developed, and evaluated to illustrate and validate the integration of temporospatial elements into one or more everyday VE contexts. Examples of such real-world scenarios include immersive surgical operations, dancing, painting, and cooking.

We aim to re-explore how temporal and spatial elements can enrich interaction within the virtual reality (VR) contexts, identify the optimal method to integrate these elements, and to determine their impact on the overall immersion and user experience. The purposes of this paper are: (1) to open a discussion about the challenges and needs associated with temporospatial design in everyday VR contexts, (2) introduce temporospatial design elements that can be utilized to enrich interaction within 3D contexts, and (3) demonstrate real-world scenarios designed to benefit from temporospatial-based interaction.

2 BACKGROUND

The subject of time and its perception are still under exploration by various researchers in many fields [1]. When it comes to interactive systems, while games explored very creative temporospatial design (e.g., Braid [11]), only few researches have looked into this aspects of VR systems as a design space that needs to be charted and methodologically validated [14].

Space is limited within the context of standard desktop tasks due to the limited onscreen area for interaction. Other contexts such as VR systems are inherently rich in space. Surprisingly, only a few VR systems have integrated creative temporospatial elements in their design.

The work of Stoev et al. [13] represents the first attempt to enable exploration of past events of historical data by proposing a visualization toolset with time manipulation capabilities. Sugimoto et al. [12] implemented a teleoperation interface inspired by temporality to augment users' vision when navigating remote spatial areas. More recently, the work of Herbst et al. [7] attempted to apply temporal aspects by visualizing historical shades of objects at certain locations, as a simple way of allowing users to travel in time. However, the work described in their report [7] only supports temporal-based navigation in historical contexts with limited interaction capabilities. Thus, the user has benefits from time travel, but is essentially a passive observer of events as opposed to actively interact with the surrounding space

Current practices of time design assume a passive approach in which the system waits for the user to drive the interaction. Thus, the system seems to be inactive and isolated from time when the user stops using it [8].

Clearly, task efficiency has been a major goal of time design [4]. However, Hallnäs and Redström [6] explored time design for reflection and learning, essentially aiming at "putting back time" into design after it has been ignored for efficiency concerns.

Time has also been part of creative usage in the entertainment domain including film, TV and games. Traditional storytelling usually manipulates the sequence of events/actions to draw attention, to set and emphasis, to introduce different explanations for events, and to highlight the small differences between fiction and reality. Games utilize time design with a more active

*e-mail: aezzelde@ucalgary.ca
†e-mail: wonhyung.ryu@gmail.com
§e-mail: sonny.chan@ucalgary.ca
‡e-mail: ehud@cpsc.ucalgary.ca
¶ e-mail: smcosta@ucalgary.ca

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approach with regards to interaction [14]. Similar to time, game space is also important in the understanding of game design and game experience [14]. We argue that the same creative approach to temporospatial we see in games can be applied, and further explored, in the context of efficient, task oriented, everyday VEs.

3 Rethinking Temporospatiality

The lack of intuitive utilization of time-and-space within interactive virtual environments is the main motivation of this research. We aim to explore how temporospatial elements can enrich the design and usage of interaction within 3D spatial interactive virtual environments, and improve the user experience.

Exploring temporality has been common in many research studies within HCI and, as discussed earlier, time design is often related to general task concerns such as perception, duration estimation, or response time. In general, when we integrate time in our VE design, we should not add it as another passive element (e.g., a configuration parameter of the system). Rather we should strive to make it visible, and possibly flexible, just as we design the VE spatial variables. Think of simulation tools that allow a civil engineer to shift time and be able to anticipate how the building structure will be affected over time, or a student who can learn about history in a more active way by time travelling and experiencing historical sites as if was living in a different era/time. On the contrary, the interaction design of standard desktop tasks (including browsing or writing) aims to support efficiency and usability, wherein time is often abstracted, discretized, or reshaped as aspects of the designed task (e.g., task time, waiting response time).

The design of virtual environments in everyday people's spaces can be different from controlled settings. Users often aim to relax and be comfortable in their home or office spaces and the design of VR systems must take this aspect into consideration. We encourage rethinking of temporal and spatial aspects to fit the nature and context of everyday VR systems.

We decided to focus on temporospatial elements within the context of everyday virtual environments because they provide rich temporospatial contexts, and because we believe the recent advances in VR technology enable inexpensive realization of explorative temporospatial VEs in everyday settings.

VR systems generally aims to support complex processes through simulation and training and such processes increasingly depend on careful consideration of temporality and dynamic interactions. However, such systems often fail to leverage the close relation between time-and-space in design. For instance, a typical everyday VE training firefighting scenario would most likely limit users to performing specific actions that constitute a linear approach to the firefighting task. Users will typically follow a predefined sequence of operations without having the flexibility to re-order certain actions or to manipulate the rate at which they occur within the VE. Alternatively, if the design gives users flexible temporospatial interactions, including the ability to manipulate time or control the action rate so that they become slower or faster as needed, users may gain better reflection and engagement with the temporospatial elements of the VEs.

An important question here is how to create and foster a continuous experience wherein the user feels constantly present in space and time (i.e. awareness of temporal change). For example, if a person is to watch a movie through VR in her home, how can the experience be designed to continuously provide immersion as if she watching it in a cinema. Here, the design of a VR system may take into consideration the location and orientation of the person`s couch, in relation with other chairs, in order to enable a unique VR cinema experience. In essence, designing the space for optimal VR experiences within people's home-spaces may need careful integration of VR tools (e.g., HMD and tracking devices) with the physical environment [10].

Exploring temporospatial aspects in VEs reflects that the design of 3D space could be utilized differently since the context of use and the possible temporal changes affect how the physical VE space can become an access point to time which could affect the user presence and the overall experience.

Another inspiration might come by connecting proxemics (i.e. perception of spatial relationship to people and devices [5]) and temporality. This may be applied in a VR home experience that leverages the spatial relationship of multiple users who share the physical space together to enable a unique VR experience, since the implicit understanding of the spatial relationship among users can be adopted as part of the design of the VR experience. For instance, imagine a VR application of dancing for users who are remotely distributed but virtually share the same space. Here, the sound and visualization of transparent trails can be carefully designed to guide users and optimized their dancing movement in the tight space they may have. Understanding interaction as a series of events and actions may miss the full richness of an interaction. This is particularly true as many complex usages in real world only focus on specific tasks for particular moments, instead of seeing the interaction as a trajectory along a timeline.

In general, we argue that if designers leverage users' familiarity with their spatial context and further empowered them with possibilities to control temporal aspects, their interaction strategies change from just adapting to the everyday VR context towards utilizing it in a more deep and rich manner.

4 Temporospatial Design Elements

Part of our exploration involves developing a framework for temporospatial elements that enrich user interactions within everyday virtual environments. In this context, such design aspects could be used to signify either the virtual objects or the 3D-interaction techniques. Such thinking relates temporospatial elements to visual variables [3] and the concept of signifiers [9]. For example, designers may render a particular virtual object as transparent in order to hint at it representing a future possible outcome, or show the object only using outlines to indicate that it represents a context that is less important than other rendered objects.

Three-Dimensional interaction techniques and temporospatial elements can be interlinked using the analogy of affordances [9]. Here, temporospatial elements would affect the representation of the interaction possibilities (e.g., the ability to interact quickly/slowly) and how users would perceive that (i.e. perceived affordances).

Following, we propose a set of temporospatial design elements and briefly explain how to incorporate them within a VE:

- <u>Trajectory</u>: A signifier that reflects a path which exists in 3D space suggesting a set of anticipated interaction possibilities
- <u>Shadowing</u>: refers to space cloning or time travel. An interaction may be duplicated for unique experimentation, e.g., a user can clone the current interaction scenario to experiment before completing the interaction.
- <u>Direction</u>: refers to the possible mapping of spatial division (e.g., left/right) to temporal division (e.g., past/future). For instance, an interaction that occurs in different subspaces may reflect different temporal meanings.
- <u>Velocity (rate, frequency, rhythm)</u>: relates speed of interaction from the temporal perspective to distance of interaction from the spatial perspective. E.g., performing an interaction slowly over a magnified area, with pausing (i.e. void space and/or empty time) to indicate frozen simulation.

To demonstrate how these design elements could be implemented in an everyday practical context, imagine a VR system for cooking. During the cooking task, the user needs to pour water quickly over a mixture of ingredients. The system may utilize the temporospatial element of "trajectory" to guide the user about potential interaction possibilities (e.g., hint at the next ingredient to be added as shown in the bottom of Figure 1). The trajectory of interaction can be further enriched when combined with the temporospatial variable of "velocity", encouraging the user to perform this action quickly, e.g., by animating the dotted trajectory that links between the water jug and the container with the mixture. Here, the dots in the trajectory are visualized with movement speed reflecting how quickly the user should perform the task. Without such temporospatial augmentation, the user may not interact quickly enough and the cooking ingredients would become spoiled.

A unique utilization of temporospatial design elements may involve what we termed "tree of experiences", a representation that reflects snapshots of previous, and possibly future, user interactions over time (Figure 1 Top). This temporospatial representation serves to provide the user with the ability to navigate back and forth in time to a particular moment and to try different actions (i.e. branching the tree).

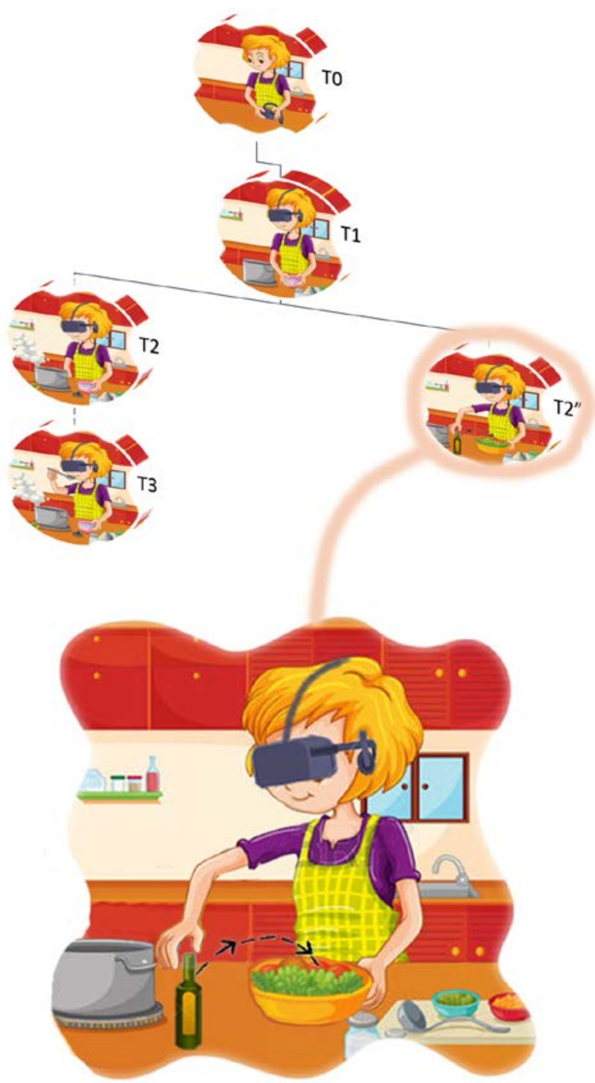

Figure 1: Bottom: An animated trajectory hints the user at the need to add the content of the bottle to the ingredient mixture, Top: shows an example of the sequence of interactions and with the tree's nodes reflecting key interaction moments.

4.1 Illustrative Temporospatial Examples

To better demonstrate the potential of exploring and supporting temporospatial elements, we highlight through the following two scenarios how temporospatial elements can be utilized within everyday virtual environment contexts.

1. Imagine a virtual reality (or augmented reality) environment supporting cooking simulation. In this regard, the space for cooking is organized into sub-spaces each may reflect a particular time connotation. For instance, the cooking space to the user's left may represent a storage of past actions performed by the user, or it may be utilized to simulate different temporal rates (e.g., objects therein would heat quickly). Moreover, the left space may be divided vertically to reflect scaling of the simulation rate. For example, items in the top-left area can heat much faster (e.g., using simulation rate t1) while items on the bottom-left area can heat a bit slower (e.g., using simulation rate t2). In this regard, temporospatial elements such as "direction" and "scale" (i.e. velocity) have been utilized, affording and providing more possibilities to the user when engaging within the 3D interactive context. Similarly, the cooking space to the user's right may reflect an area for future possible actions, where the simulation is presenting possible future implications of different actions (some for example presenting the ready dish, or a burned version of it), or wherein the simulation rate is moving faster than the normal rate (e.g., items therein would cool quickly). In essence, the utilization of temporospatial elements in this example highlights a unique way of subdividing some of the spatial elements of the VE based on temporality.
2. Imagine a scenario wherein a user is interacting with an everyday task, and, for example, is about to enter a VE office environment. The user may immediately see shadows of oneself at different potential locations inside the room as if she was interacting with certain objects (e.g., a particular shadow may reflect the user previous interactions with the VE, for example reading a book or a past representation of herself chatting with another person). The transparency of such reflections (e.g., footsteps, volumetric shadows, or halos) may differ hinting at more valid, more recent interaction, past or future possible trajectories. Also, such reflections can be utilized and followed based on the user's goal or on her current/previous behavior, thus representing a more active form of simulation where the VE spatiality enables rich interaction with time.

4.2 Temporospatiality in Practice

To further validate temporospatial elements we are currently exploring the design and implementation of a surgical VR system that will integrate some of these temporospatial elements through multi-disciplinary research collaboration with the Faculty of Medicine. Our user survey with expert surgeons yielded positive feedback on the potential benefit of temporospatial design elements, particularly in the educational setting.

We are exploring temporospatial-based interaction through a virtual training prototype wherein surgery trainees practice a common spine surgical procedure of pedicle screw insertion for spinal instrumentation. In this regard, we are re-exploring the design of various temporospatial elements to enrich interaction in the context of surgical education. For example, we are examining the effect of altering haptic-feedback, a temporospatial variable representing tactile changes overtime, in achieving different tactile sensation that are critical for surgical procedures. Furthermore, we are developing novel method of manipulating the “scale” of the spine model aimed to enhance the users’ anatomical learning during the simulation. Lastly, we are incorporating unique visual cues through providing “trajectory” of inserting the pedicle screw in order to guide users and hint them at the optimized placement and to help them avoid hitting the spinal cord and exiting nerves. These temporospatial elements were received positively by our surgical collaborators, and we are currently finalizing the integration of these elements prior to conducting formal evaluation of their practicality.

Immersive dancing or painting can be suitable everyday VR examples, and the design of such applications would benefit from temporospatial elements. For instance, the trajectory of dancing can be visualized with an animation that guides user to perform certain movements in space over time; hinting at the sequence of the dance. Furthermore, a user can be in the shoe of another user ensuring their continuity in such temporospatial interaction. Also, designers may enable freezing time so that users can see the traces of their dance, and share it with friends. Immersive painting similarly empowered by temporospatial design elements may enable people to navigate and explore drawings that existed moments ago.

5 Conclusion

Current design practices of temporality in everyday interactive systems often pay little attention to the rich, open-ended temporospatial possibilities that VR enables. Our research attempts to open a discussion and provide insight into the challenges and needs of temporospatial elements in VR in order to enhance user immersion and engagement.

We discussed that a rethinking of spatial and temporal aspects in the design of everyday virtual environments is beneficial. We demonstrated through home VR examples how temporospatial elements can be used in practice. We hope that this research will encourage further discussion and consideration of temporospatial design elements in the design of everyday VR systems.

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