Geometric deformation for reducing optic flow and cybersickness dose value in VR

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Abstract

Today virtual reality technologies is becoming more and more widespread and has found strong applications in various domains. However, the fear to experience motion sickness is still an important barrier for VR users. Instead of moving physically, VR users experience virtual locomotion but their vestibular systems do not sense the self-motion that are visually induced by immersive displays. The mismatch in visual and vestibular senses causes sickness. Previous solutions actively reduce user's field-of-view and alter their navigation. In this paper we propose a passive approach that temporarily deforms geometrically the virtual environment according to user navigation. Two deformation methods have been prototyped and tested. The first one reduces the perceived optic flow which is the main cause of visually induced motion sickness. The second one encourages users to adopt smoother trajectories and reduce the cybersickness dose value. Both methods have the potential to be applied generically.

CCS Concepts

• ***Computing methodologies*** → ***Virtual reality; Perception; Mesh geometry models;***

1. Introduction

Virtual reality (VR) applications are no longer confined to gaming. Cheaper and better VR hardware has encouraged more and more applications in workplaces. Many novice VR users have not yet got used to navigation and perception in virtual environment and they can feel discomfort during their virtual experience due to visually induced motion sickness (VIMS). According to the sensory conflict theory, VIMS is provoked during a VR experience when humans perceive incoherently self-motion through vision and vestibular senses. Instead of moving physically, VR users send commands using devices (e.g., gamepad) to move in virtual worlds. Users can feel visually induced self-motion but they do not feel any movement according to their vestibular systems. This incoherent movement perception can provoke cybersickness among susceptible users which is half of the world population.

Two objective measures have been shown to influence VIMS: the optic flow generated from visualized images [JFR04] and the cybersickness dose value (CSDV) [So99] generated by navigation. The optic flow is motion of light seen in human eyes when human watch illuminated objects moving. It is represented by a vector field in which the light pattern velocity at each point of the field of view (FOV) is quantified. The VR immersion will let users to absorb completely the generated optic flow. The CSDV is related to the acceleration and exposure time during navigation and jerky trajectories will enhance the acceleration suffered by users.

2. Related work

Various VIMS counter-measures in VR can be found in the literature to reduce the self-motion differences perceived by vestibular and visual senses. They either enhance the vestibular sensation or reducing visual sensations.

Locomotion simulators allow user to walk as in a real life in a restricted zone during VR experience, e.g. an omnidirectional treadmill system [FCSE13]. Human vestibular system sensation can be altered though galvanic stimulation [MAA*05] to feel physical acceleration or balance changes. These solutions can be harmful, complicated or expensive for personal usage.

On the software level, VR systems can actively alter either user visualization or navigation. To reduce the VIMS during VR navigation, the user field of view (FOV) can be decreased dynamically [FF16], the user locomotion speed can be adapted [Argelaguet 2014] or replace by carefully calibrated automatic navigation [WCM19]. These approaches can reduce the quality of immersion or the navigation controls.

In this paper an original approach is proposed on the software level to deform geometrically the virtual environment according to the user navigation. Our method is passive and will not degrade user navigation nor visual perception in the virtual world. Actually the deformation is applied on the virtual environment passively and we do neither alter actively the user navigation nor visualization. Two deformation approach have been devised and prototyped. The first

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one allows to reduce the optic flow perceived in the scene visualization and the second one allows user to improve their navigation trajectory and reduce the cybersickness doses value (CSDV).

3. Scene deformation for reducing optic flow

The first approach consists of dynamically and temporarily deforming the geometry of the surrounding virtual scene during navigation so that the relative motion of the scene perceived in the user peripheral vision is reduced. The idea is to encapsulate the virtual environment into a regular grid to deform as a whole [SP86]. When a user is navigating, the part of environment located in the user peripheral vision will be deformed, i.e. compressed in the navigation direction. This approach has been firstly proposed and experimented in [LC19] and the participants felt subjectively a reduced navigation velocity in the deformed scene.

This method has been further investigated in order to analyze the generated optic flow that is related to visually induced self-motion [JFR04]. The optic flow has been analyzed on the rendered images both for normal and deformed scenes during navigation (fig. 1). We discover that the Scene deformation can significantly reduce the peripheral optic flow in the visualized images (p<0.001, paired t-test) without changing the optic flow at central view.

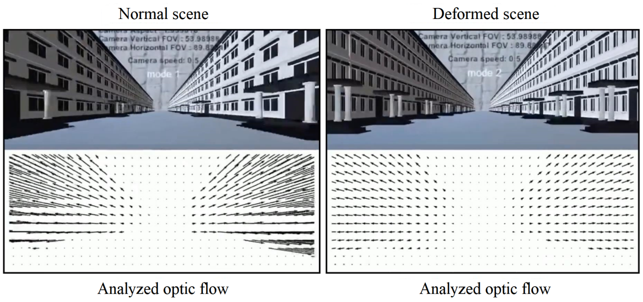

Figure 1: *Optic flow comparison*

4. Scene deformation for reducing CSDV

The second approach aims to deform the environment so that user can realize smooth navigation trajectories. Since users express their intention of locomotion through input devices and the visual perception of the virtual environment is limited by the FOV, users realize jerky navigation trajectories to avoid collision with the obstacles in virtual environment. An experimental virtual environment composed by walls has been designed (fig. 2.a). According to the location of user the nearby walls are deformed dynamically in order to facilitate the navigation and minimize the collision between user and the walls (fig. 2.b. Two user positions have been shown and the green spheres are safety buoys to trigger the wall deformation before the real collision between user and walls.

Two navigation trajectories have been realized respectively in normal and deformed scenes (fig 2.c) and are interpolated by cubic polynomials so that the second derivatives (acceleration) can be calculated (fig. 2.d). The trajectory realized in deformed scene is much smoother and the acceleration peak is lower. The CSDV proposed in [So99] has been computed and the ratio of CSDV in deformed scene to normal scene is 0.49.

5. Conclusion

This paper proposes the use of geometric deformation of the scene to reduce motion sickness in VR. Two deformation approaches have been implemented and analyzed. The first approach significantly reduces the optic flow perceived in the rendered images. The second approach can guide users to adopt smoother navigation trajectories so that the cybersickness dose value (CSDV) is reduced by half. These investigations confirm the effectiveness of the geometric deformation to reduce motion sickness in VR. In the future, the first approach will be updated to cover rotational navigations. Both methods can potentially be implemented in a generic way through a deformation engine. The challenge is to determine levels of deformation. Future work to modify CSDV to a predictive model so as to estimate the optimal deformation parameters are desirable.

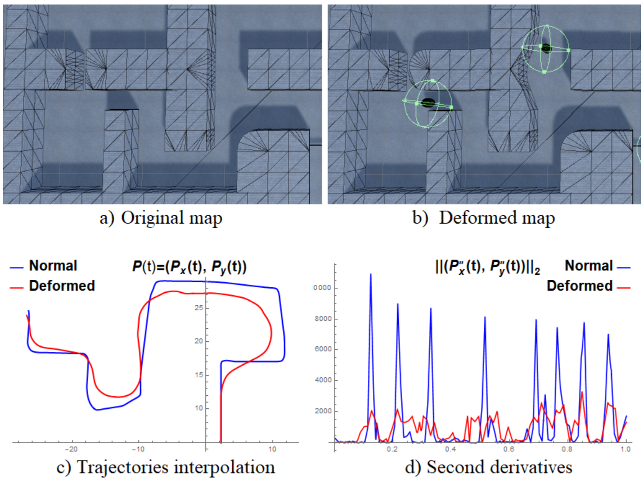

Figure 2: *Navigation trajectories comparison*

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