
4D Experiences Enabled by Automatic Synthesis of Motion and Vibrotactile Effects

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Abstract

4D experiences are one of the most immersive kinds of experiences that current virtual reality technologies can offer. However, the production of 4D contents is still very labor-intensive, and it has been a major obstacle against the wider spread of 4D platforms. In this demonstration, we present two methods that generate motion and vibrotactile effects automatically from the audiovisual content of a movie. Our synthesis methods provide compelling 4D experiences to viewers while greatly improving the productivity.

Author Keywords

4D, motion, vestibular, vibrotactile, sensory substitution

ACM Classification Keywords

H.5.1 [Information Interfaces and Presentation (e.g. HCI)]: Multimedia Information Systems-Artificial, augmented, and virtual realities; H.5.2 [Information Interfaces and Presentation (e.g. HCI)]: User Interfaces-Haptic I/O

Introduction

4D platform is an immersive entertainment system that presents various physical effects with audiovisual content to improve viewers' multimedia experiences. Providing convincing 4D experiences has become an indispensable means in various simulators, attractions, theaters, and games. Current 4D effects mostly rely on motion (vestibu-

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Figure 1: Personal motion chair.



Figure 2: Tactile pad.

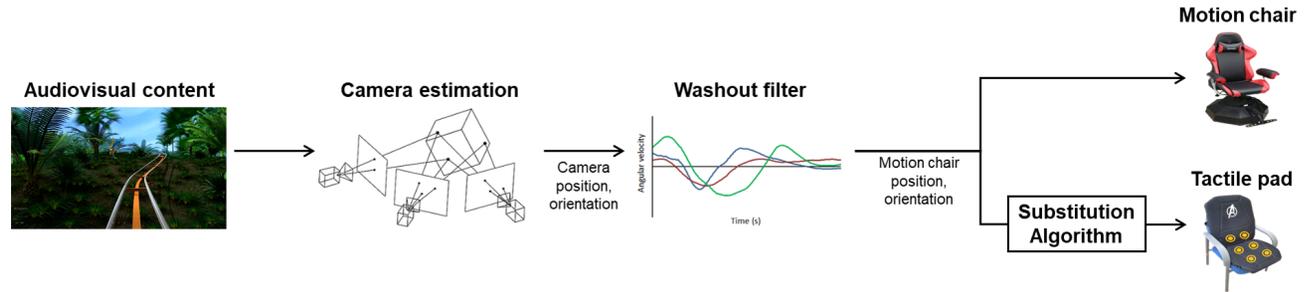


Figure 3: Flow of the automatic synthesis algorithms.

lar) and vibrotactile feedback, which take almost 80% of the 4D effects used in 4D rides and films [2]. However, the labor-intensive nature of 4D effects production is a serious bottleneck against the growth of the entire 4D ecosystem, along with the expensive prices of motion platforms.

In this demonstration, we present two methods that automatically generate motion and vibrotactile effects, respectively, by analyzing the audiovisual content of ride films. Such automatic synthesis can greatly facilitate 4D effects production. While watching 4D ride films using a head-mount display (HMD), users can experience compelling 4D effects using a personal motion chair that has two DOFs (degrees of freedom; roll and pitch; Figure 1) or a tactile pad, which has an array of six vibration actuators, placed on a regular chair (Figure 2). Some further details on the conversion algorithms are provided in what follows.

Demonstration 1: Motion Effects

Our synthesis algorithms of motion effects [2] consist of two phases: one to estimate camera motion from video sequences and the other to make motion commands from the estimated camera motion. The first phase computes the relative angular velocities and linear accelerations of vir-

tual camera between consecutive frames using the epipolar constraint. The overall procedure is optimized to synthesizing plausible motion effects for viewers. The second phase determines position and orientation commands to a motion chair from the estimated camera motion. To this end, we use a washout filter [3], which is a standard high-pass filter for motion simulation with a proven convergence property to the initial state. The fast camera effects automatically synthesized by our algorithms are generally of high quality, even comparable to manually-made motion effects (see user studies in [2]). This procedure is delineated in Figure 3.

We will use a personal motion chair with two DOFs for the demonstration. Since this chair can move only in roll and pitch (Figure 1), the camera motion variables in the full six DOFs are reduced to chair roll and pitch using the rules described in [2].

Demonstration 2: Vibrotactile Effects

Motion chairs can make very strong effects for 4D experiences, but the equipment for that is still quite expensive. An alternative is to use a tactile pad that has a large number of vibrotactile actuators. This process corresponds to sen-

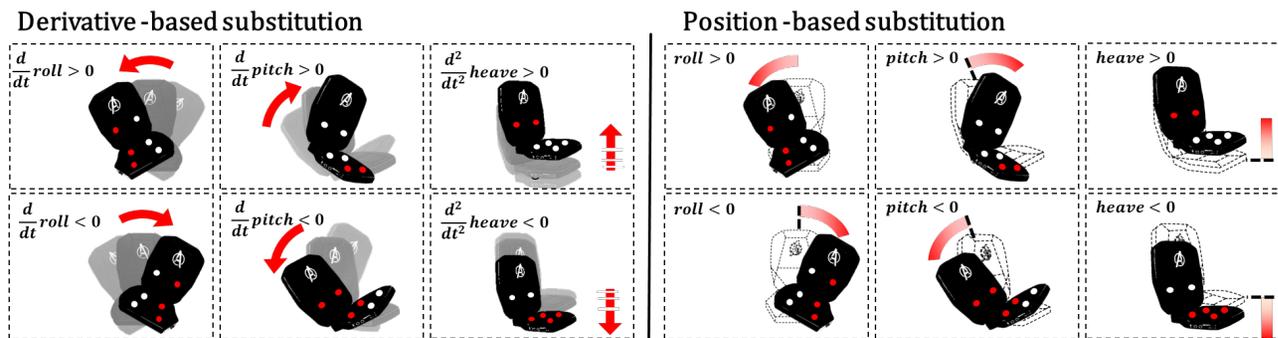


Figure 4: Two substitution algorithms.

sory substitution, and our goal was to effective algorithms that mimic motion effects using only vibrotactile stimuli. The challenge was how to overcome inherent perceptual differences between motion and vibrotactile stimuli and provide similar information and experiences to the user.

We have designed two substitution algorithms on the basis of the fact that viewers perceive motion from vestibular or visual cues. One algorithm is a physically-faithful imitation of vestibular feedback using vibrotactile cues, and it uses the first- and second-order derivatives of the motion variables.¹ The other algorithm is more perception-oriented, and it matches visual and vibrotactile cues in more intuitive manner. The algorithm relies on only the motion variables without their derivatives. The two algorithms are depicted in Figure 4, and further details will be presented at the 2018 CHI [4].

¹The human vestibular system responds to only linear acceleration, but not linear velocity, and also senses angular velocity through the linear acceleration occurring in rotational motion [1].

Our user study showed that the position-based substitution rule generally outperformed the derivative-based rule [4], but it depends on the content of the movie.

Summary

Our group has been exploring methods to popularize 4D contents further. Our current contributions are automated synthesis algorithms of motion and vibrotactile effects, which otherwise need to be designed manually. In this demonstration, users will have opportunities to experience automatic motion and vibrotactile effects, respectively, both added to the audiovisual stimuli of ride films, and compare the experiences of the two platforms. Some more details about the setup of our demo are available in the supplementary video submitted together. To the best of our knowledge, our solutions are unique for their kinds, and we expect that this demo will provide interesting experiences to users as to the advancements of virtual reality technologies.

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