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# Toward Haptic Cinematography: Enhancing Movie Experience with Haptic Effects based on Cinematographic Camera Motions

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## Abstract

Haptics, the technology which brings tactile or force-feedback to users, has a great potential for enhancing movies and could lead to new immersive experiences. In this paper we introduce *Haptic Cinematography* which presents haptics as a new component of the filmmaker's toolkit. We propose a taxonomy of haptic effects and we introduce novel effects coupled with classical cinematographic motions to enhance video viewing experience. More precisely we propose two models to render haptic effects based on camera motions: the first model makes the audience feel the motion of the camera and the second provides haptic metaphors related to the semantics of the camera effect. Results from a user study suggest that these new effects improve the quality of experience. Filmmakers may use this new way of creating haptic effects to propose new immersive audiovisual experiences.

## Keywords

haptic, cinematography, audiovisual experience

## 1 Introduction

Increasing the user's immersion is both a key objective and challenge of multimedia applications. For decades, research has mainly focused on improving image and sound. But this multisensory experience is now extended to others senses than sight and hearing. In particular, the sense of touch (haptics) seems to display a great potential in multimedia [11]. Indeed, O'Modhrain and Oakley have observed that the haptic technology already used in virtual reality or video games leads to immersive and intense user experiences [13].

So far haptic-audiovisual (HAV), where users see, hear and physically feel the content, is mostly experienced in “4D cinemas” or amusement parks. But new devices are developed to bring this technology to consumers. A typical example is the seat developed by the D-Box company[1]. With the provision of new haptic devices, appears the necessity to create new HAV contents, and to design new modalities for the creation of haptic effects [5].

In this paper, we propose **a taxonomy of haptic effects** that classifies potential haptic effects for audiovisual content and the context in which they may be used. We dubbed this approach *Haptic Cinematography*. We identified in the literature that haptic effects often represent physical events occurring in an audiovisual scene. However many other aspects could be enhanced. In particular coupling haptic effects with cinematographic camera motions has not been addressed. Hence we introduce a **new type of haptic effect related to camera motions** (referred as camera effects) that are used by movie makers to convey meaning or to create emotion. Our hypothesis is that haptic feedback can enhance these cinematographic effects and consequently the quality of video viewing experience. We propose **two models to render camera effects on haptic devices**. The first model is designed to make the viewer feel the movement of the camera, the second provides a haptic metaphor related to the semantics of the camera effect.

Finally a user study was conducted to evaluate the relevance of our approach and we report the results. They suggest that **the quality of experience is improved by haptic feedback**. Besides, the two models yielded different results that are useful to identify design recommendations for haptic effects.

The literature on haptic-audiovisual content is first reviewed in section 2. Then the taxonomy and the new haptic effects based on camera effects are detailed in section 3. The proof-of-concept is described in section 4, followed by the user study in section 5. Discussion and conclusions end the paper (sections 6 and 7).

## 2 Related Work

Haptics has been widely used in virtual reality applications to increase the user’s feeling of immersion. Hence there is a growing interest among researchers in integrating haptic feedback into audiovisual systems (the reader can refer to a survey published on this topic by our group [5]). Three main challenges have been identified: the production, the distribution and the rendering of haptic-audiovisual content. In this paper we focus on the production of HAV content. Three means are generally considered in the literature. First, haptic feedback can be manually edited (most encountered situation). An audiovisual (AV) content is produced and haptic effects are created during the post-production stage through dedicated editors [18]. Second, haptic effects can also be created automatically by extracting data from the AV content or from metadata. For example, events from a soccer game video may

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[1] http://www.d-box.com

be extracted and then displayed with a vibrating device [17]. Finally haptic content may be directly captured during the production stage with physical sensors. The idea is to collect haptic data related to an object or actor in a scene. In a previous work, we have placed a camera together with an inertial measurement unit (IMU) on an actor's chest to capture a first-person point-of-view video and the associated motion [3]. Data from the IMU are then used to drive a haptic device while the user is watching the video.

An important aspect in the creation of HAV is the synchronization of haptic effects with the AV content. We have observed from the literature that haptic effects are mostly used to represent physical events which occur in the scene [5], for example haptic effects related to the onscreen character [13, 8]. This is the paradigm used in virtual reality for increasing the user's feeling of immersion. Yet haptic effects may highlight other aspects of a movie. Lemmens et al. have developed a jacket supposed to increase the user's emotional response during movie viewing [10]. Here haptic feedback is related to the ambiance or emotion of the movie. More generally haptic feedback may enhance a range of components in audiovisual content and could be considered as a special effect equivalent to visual or sound effects.

# 3 Haptic Cinematography

Cinematography encapsulates both the art of making movies and the associated techniques (camera work, staging, lighting, sound, montage) [15]. In order to improve users' experience, many others effects have been added: special visual effects, spatialiazed sound, 3D technology, etc. and we believe that haptics may also be included in the filmmaker's toolkit.

We introduce the concept of *Haptic Cinematography* which represents the techniques to create haptic effects in order to produce a HAV content and organize effects in a taxonomy (see Figure 1).

## 3.1 Taxonomy of Haptic Effects

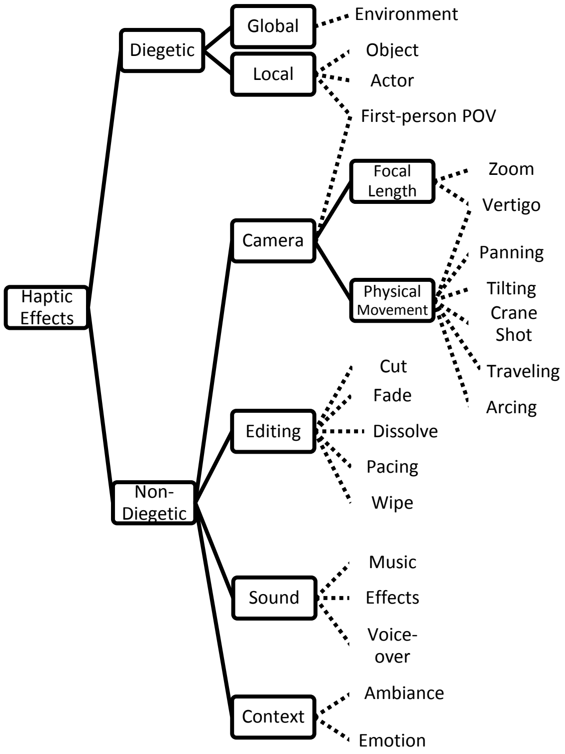

Figure 1: Taxonomy of haptic effects for audiovisual content. Items in boxes are categories and those linked with dash lines are examples.

A parallel can be drawn between the role of haptic effects and the one of audio in movies: audio is used for increasing the realism (sound effects) but also to create ambiance (music). These two categories of audio content are known as diegetic sounds, a sound for which the source belongs to the diegesis (the recounted story), and non-diegetic sounds, a sound for which the source is neither visible nor implied in the action, typically such as a narrator's comment or mood music [15]. In a similar way, haptic effects can be classified into diegetic and non-diegetic effects.

Diegetic haptic effects can enhance physical events happening (and usually visible) in the audiovisual content in a similar way to how haptic effects are used in virtual reality applications. Two subcategories may be identified: local or global. Local effects are associated to one object in the scene: e.g. force-feedback [13] or vibrations [8] related to events occuring with an onscreen character or vibrations representing the position of the ball in the soccer game [17]. Global effects refers to effects related to the environment. This could be vibrations associated to a earthquake in a movie or a system allowing users to touch the objects within the scene (see Cha et al.'s touchable TV [1]).

Non-diegetic effects refer to elements not attached to the fictional world depicted by the story. Davenport et al.'s have proposed a model of the shot which includes non-diegetic elements [6]. From this model, we identified four categories of non-diegetic haptic effects. The first category of effects is related to non-diegetic sounds (i.e. music, voice-over, etc.). Here haptic effects would highlight particular sound effects or music [9]. In a second category, haptic effects underline the context, i.e. the ambiance or emotion (Lemmens et al.'s jacket [10]). More generally the design of such effects would take advantage of research results in affective haptics to convey emotion through haptic feedback [16]. A third category contains effects related to the camera parameters, focal length and physical movement, which are used by movie makers to achieve visual effects. Editing techniques could be used in a similar way. The editing process is another tool employed by movie makers to convey emotion or meaning [15]. For example the "pacing", the rhythm due to the succession of shots, may create tension. A haptic effect could follow this rhythm to increase the tension.

To the best of our knowledge, no work relied on the camera or editing to create haptic effects. Similar techniques may exist in the field of virtual reality where the user can manipulate the camera. But our paper fundamentally targets a different context: the association of haptics to cinematographic elements. There is no interaction and the aim is more to increase the cinematic experience than only moving the user's point of view. These cinematographic techniques are intensively used to convey meaning or emotion. Our hypothesis is that haptic feedback may underline these effects and therefore improve the quality of the video viewing experience. To illustrate this approach we focus on enhancing camera effects with haptic effects.

## 3.2 Camera Effects

A camera effect consists in modifying the camera parameters such as the position of the camera or the focal length to obtain a specific visual effect [15]. If there is no strict rule, camera effects are generally associated

| **Camera Effect** | **Description** | **Purpose** | **Camera Parameter** |
|---|---|---|---|
| Crane Shot | Vertical movement such as a lift-off | Feeling of omniscience over the characters | $y_c, \phi_c$ |
| Dutch Angle | Tilting to a side | Underline physiological uneasiness or tension | $\psi_c$ |
| Arcing | Circle movement around the framed object | Increase the importance of the scene | $x_c, z_c, \theta_c$ |
| Traveling | Lateral movement | Follow an object or actor | $x_c$ |
| Tilting | Rotation in a vertical plane from a fixed position | End with low angle: feeling of inferiority regarding the framed object | $\phi_c$ |
| Zoom-in | Modification of the focal length | Attract attention toward an object | $\gamma_c$ |
| Vertigo | Zoom-out while the camera moves forward | Sensation of vertigo or strangeness | $z_c, \gamma_c$ |

Table 1: Cinematographic camera effects. They are typical movements along one or more degrees of freedom and/or a modification of the focal length and they are usually associated to a specific meaning [12, 15]. The last column indicates which parameters of Equation 1 are modified in order to generate the effect.

to a specific purpose. For example, the "Vertigo" effect, also known as "Dolly Zoom", has been democratized by Alfred Hitchcock in his Vertigo movie released in 1958. This effect is a combination of a zoom-out and a forward movement of the camera. The result is that the environment around the framed object is being distorted, which induces a sensation of vertigo.

We identified seven main representative camera effects from the cinematography literature [12, 15]: three movements (Crane Shot, Arcing and Traveling), two rotations (Dutch Angle and Tilting), one modification of the field of view (Zoom) and Vertigo. Table 1 describes how they are created and the purpose for which they are commonly employed.

### 3.3 Haptic Effects Based on Camera Effects

We designed haptic effects to underline the visual effects achieved by the camera motions: the vertigo sensation of the Vertigo effect, the feeling of instability triggered by a Dutch Angle or the movement of the camera during a Traveling.

We proposed two different models to render haptic effects based on camera effects. The first one aims at making the user feel the movement of the camera (a zoom is considered as a forward movement). This model is called *Cinematic Model.* We assume that information about the position, pose and field of view of the camera is available and can be used to drive a haptic device. The second model renders a haptic effect which is related to the purpose of the cinematographic effect (see Table 2). We dubbed this model *Semantic Model*. In this case the effect is manually authored and would be designed as a metaphor for the cinematographic effect.

Both models convert the camera effect into a haptic feedback. Then their implementation depends on the targeted haptic device. But the concept is applicable to any type of haptic device: force-feedback devices, tactile devices or even to motion platforms.

# 4 Proof-of-Concept

To evaluate the relevance of our approach, we have created seven video sequences illustrating the camera effects listed in Table 1. Then our two models were implemented and designed to render effects on a *HapSeat*, a novel haptic device which simulates sense of motion [4].

## 4.1 Audiovisual Content

As already mentioned in the related work section, there are several ways to generate a video augmented with motion data: camera properties may be captured during production [3], they may be extracted from metadata in the AV content or they may be computed from image processing algorithms [14].

Here a 3D engine has been used to generate video sequences illustrating the seven camera effects. We used a classical camera model to represent the position of the camera in space (Cartesian coordinates $x_c, y_c, z_c$), its orientation (three Euler angles $\phi_c, \theta_c, \psi_c$) and the value of its field of view, $\gamma_c$, for each instant $t$ [2]:

$$C^t = [x_c, y_c, z_c, \phi_c, \theta_c, \psi_c, \gamma_c]^t \tag{1}$$

The 3D scene shows two characters animated with an idle behavior in a building (see Figure 2). The scene is voluntarily neutral to highlight the camera effect and to avoid potential distracting elements. The cinematographic effects were produced by modifying the camera parameters. For example a Traveling is a modification of the $x_c$ parameter or a Tilting is a change of the $\phi_c$ parameter (see Table 1). The duration of a sequence was seven seconds: the camera stayed still for the first second, then camera parameters were modified in a way to produce a continuous effect during five seconds and finally it stayed still again for one second (hence reproducing the classical usage of cinematographic camera motions in movies).

## 4.2 Haptic Device: the HapSeat

Haptic effects were rendered on the *HapSeat* [4]. This setup simulates motion sensations in consumer settings using local force-feedback devices. It relies on three low-cost force-feedback devices (Novint Falcons) held by an armchair-shaped structure. Two of them stimulate the user's hands while a third one stimulates the head. These three points of stimulation aim at generating a 6DoF sensation of motion (see Figure 3 - left). The three devices move all together in a single direction to render a translation. For rotations they move as if there were three points of a plane rotating around the user's chest.

In the remainder of this paper the following notation is used (see Figure 3 - right).

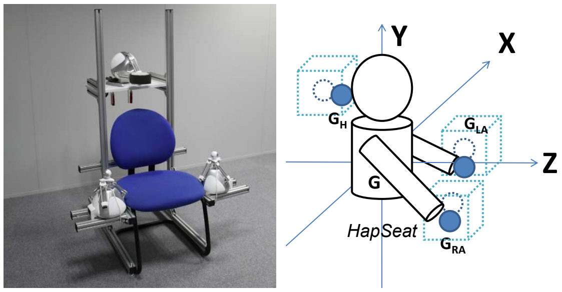

Figure 3: HapSeat. Device (left) and schematic representation of effectors on the user's body (right)

The actuators near the head, left hand and right hand are labeled $H$, $LA$, and $RA$. Their central positions in their workspaces are named respectively $G_H$, $G_{LA}$ and $G_{RA}$, $G$ being the center of the space. The size of the workspace of one actuator is $10 \times 10 \times 10$ cm.

### 4.3 Cinematic Model

The purpose of this model is to mimic the movement of the camera for which all parameters are available.

The command law to control one local actuator A is formulated in terms of displacement from its initial and central position $G_A$ to the new position $G'_A$:

$$\overrightarrow{G_A G'_A} = f(\vec{T}, \vec{R}, \vec{F}) \tag{2}$$

where

$$f(\vec{T}, \vec{R}, \vec{F}) = \frac{\|\vec{T}\|\vec{T} + \|\vec{R}\|\vec{R} + \|\vec{F}\|\vec{F}}{\|\vec{T}\| + \|\vec{R}\| + \|\vec{F}\|} \tag{3}$$

and

$$\vec{T} = \begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \end{bmatrix} \tag{4}$$

$$\vec{R} = (R_x(m_x\phi_c(t))R_y(m_y\theta_c(t))R_z(m_z\psi_c(t)) - I_3)\overrightarrow{GG_A}) \tag{5}$$

$$\vec{F} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & s_z \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \gamma_c \end{bmatrix} \tag{6}$$

The function $f$ is the combination of three vectors $\vec{T}$, $\vec{R}$ and $\vec{F}$ which respectively uses the positions, pose and focal length parameters of the camera model (Equation 1). $k_x$, $k_y$, $k_z$, $m_x$, $m_y$, $m_z$, $s_z$ are some scaling factors to map the motion of the camera in the workspace of the actuator. $R_x$, $R_y$ and $R_z$ are the 3D rotation matrices around their respective $X$, $Y$ and $Z$ axes and $I_3$ is the identity matrix of $R^3$.

From this equation, the new application points $G'_H$, $G'_{LA}$ and $G'_{RA}$ are computed from the initial points $G_H$, $G_{LA}$ and $G_{RA}$. The scaling factors are computed to use the workspace of each actuators in an optimal way, by finding a compromise to avoid any saturation while using the largest space available. The computation of those scaling factors is performed by a preprocessing step consisting in finding the maximal amplitude of displacement rendered by the three different actuators.

The output of this model is specific in the case of the Vertigo effect. The effect is composed by a combination of a forward movement (input of Equation 4) plus a zoom-out (which is considered as a backward movement by Equation 6). Thus the model produces no movement for this effect. For the other cases the user will follow the movement of the camera described in Table 1: for the Zoom-in, the user feels a forward movement (see Figure 4); for the Dutch Angle, the user feels a rotation (left actuator goes down while the right one goes up); for the Traveling, the user feels a lateral movement; etc.

### 4.4 Semantic Model

The second model aims at evoking the purpose of the camera effect. For example, the Dutch Angle is often used to show that something strange is happening (Table 1). The associated haptic effect should therefore highlight this sensation of strangeness.

Different types of movements were designed to explore the potential of haptic feedback for camera effects. The haptic effects have been designed with a home-made editor allowing us to determine the position $G'_A$ of each actuator in time. The metaphors were rendered as linear movements for the Arcing, Tilting and Vertigo while more dynamic patterns were used for the other sequences. Moreover with the individual motions of each actuator, we created more complex sensations than the *Cinematic* model.

Figure 4 shows the difference between the two models for the Zoom-in sequence. Table 2 describes these haptic effects dedicated to the *HapSeat* and what the user is supposed to feel.

### 4.5 Haptic Rendering

The models provide, for each instant $t$ of the simulation, the target position $G'_A$ (namely $G'_H$, $G'_{LA}$ and $G'_{RA}$) for each actuator $A$ (namely $H$, $LA$ and $RA$).

Most force-feedback devices (such as the Novint Falcons) are impedance haptic devices, and the position of the actuator is thus not directly controllable. Indeed this kind of device is designed to sense the current position of the actuator and to provide a force feedback to the user. A spring-damper model is thus used to control these devices in pseudo-position. The force $\vec{F_A}$ applied to an actuator $A$ is computed by:

$$\vec{F_A} = k(\vec{G'_A} - \vec{P_A}) - d\vec{V_A} \tag{7}$$

where $\vec{G'_A}$ is the targeted position, $\vec{P_A}$ the current position of the actuator, $\vec{V_A}$ its velocity, $k$ the spring constant and $d$ the damping constant.

A haptic-audiovisual player has been developed to play back both video sequences synchronized with haptic feedback. The haptic loop runs at 1KHz and the value of the force $\vec{F_A}$ is updated at each instant $t$.

## 5 User Study

A user study was conducted to evaluate the influence of our haptic effects on the Quality of Experience (QoE [7]), i.e. the subjective user's experience with the movie. Our hypothesis is that a movie enhanced with our haptic effects provides a better user experience than with a regular movie.

Thirty-eight participants took part in this experiment, aged from 14 to 53 ($\bar{x}$=36.39 $\sigma_x$=10.47). Nine were female, 3 left-handed

| **Camera Effect** | **Metaphor** | **Description** | **Implementation** |
|---|---|---|---|
| Crane Shot | Flying away | User feels several up and down movements as a bird taking off. | Actuators are going up then down with an increasing intensity. |
| Dutch Angle | Instability | User sways from left to right, as on a boat. | Left actuator goes up while the right one goes down and vice versa. |
| Arcing | Intensification | User's hands are getting closer in a movement to represent a concentration. | All actuators are moving towards the center $G$. |
| Traveling | Crab walk | Hands movement mimic a crab walk following the camera movement. | Right actuator move toward the right. Then it slighly goes back to its initial position while the left actuator move toward the right. And so on. |
| Tilting | Inferiority | User's hands and head go down to make the user feel smaller than the framed object. | All actuators go down. |
| Zoom-in | Walk forward | User's hands movement mimic a forward walk. | Similar to crab walk except that the actuators move forward. |
| Vertigo | Vertigo | User's hands move away from each other as if the environment is being extended. | All actuators are moving away from the center $G$. |

Table 2: Semantic model. Description of haptic metaphors for camera effects.

and 9 already used a Novint Falcon. None of them was an expert user of force-feedback devices or motion platforms.

## 5.1 Experimental Plan

To evaluate the impact of our models on the QoE, we used four types of haptic feedback.

1. **Cinematic Feedback**: haptic feedback computed using the *Cinematic* model

2. **Semantic Feedback**: haptic feedback computed using the *Semantic* model.

3. **No Haptic Feedback**: only the video was displayed, the actuators remained

in the center of their workspace.

4. **Random Feedback**: haptic feedback computed from a low-pass filtered white noise (cutoff frequency $F_c = 0.5Hz$).

The *No Haptic Feedback* corresponds to a regular movie viewing session and serves as a control condition to show how the other feedback modify the QoE. The *Random Feedback*, not synchronized with the video, is used to evaluate the influence of a synchronous feedback on the QoE.

To compare the models we selected a pairwise comparison method: for each video sequence, every feedback was compared against all the others. This lead to 6 couples of haptic feedback per sequence (except for the Vertigo where the *Cinematic feedback* is equal to the *No Haptic Feedback*. There were 3 couples in this case). For our 7 sequences, we obtained a total of 6x6+3=39 couples (conditions). In order to avoid effect order, the inverse of each couple had also to be tested. Therefore each participant tried 78 conditions.

## 5.2 Procedure

The duration of the study was about 30 minutes, the participant was comfortably installed on the *HapSeat* (see Figure 5). The experiment included a training phase in which the participant experienced the seven videos associated to one of the four haptic feedback (randomly chosen). Then the 78 conditions were presented in a random order. Participants were allowed to take a break at any time. For a condition, the participant experienced one video plus an associated haptic effect, then the same video plus a different haptic effect. The requested task was to select the favorite sequence by pressing a button. The next condition was then automatically started. Finally a post-test questionnaire was submitted to collect more information about the user's experience.

The video sequences were made short, seven seconds, to prevent the experiment from being too long and too tiring for the participants. A pilot study was conducted to make sure that the duration of each video sequence was enough to complete the task.

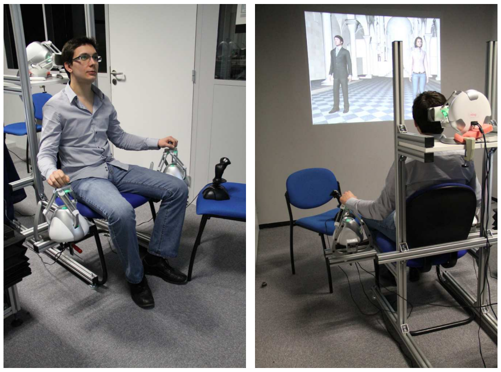

Figure 5: Experimental Setup, front view (left) and back view (right). The participant experiences haptic effects while watching a video.

## 5.3 Results

A point was given to a model each time it was chosen by a participant (scores were normalized from 0 to 1 the maximum score). The scores are displayed in Figures 6 and 7. Scores are denoted by $S_X^Y$ with $X$ for the model and $Y$ for the sequence. The normality of the distributions cannot be assumed according to the Shapiro-Wilk test. Hence non-parametric tests were used to analyze these results: Friedman Anova and

Wilcoxon test with Holm-Bonferroni correction.

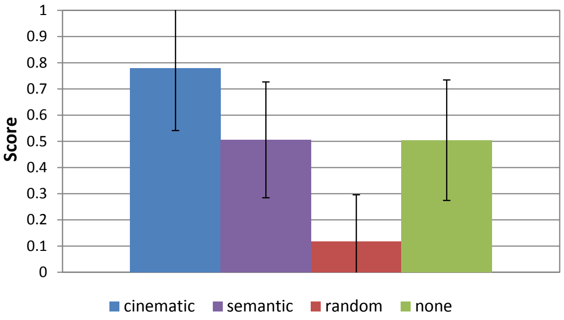

Figure 6: Average results for all sequences. The *Cinematic* model improves the Quality of Experience compared to the *None* condition.

The main result is that the haptic feedback computed from the *Cinematic* model improves the QoE (F. Anova: $p < 0.05$). The score for this model is significantly higher than the score for the *None* condition ($S_C^{All} = 0.78 > S_N^{All} = 0.5$, Wilcoxon: $p < 0.05$). The score for the *Random* condition is significantly lower than the others (Wilcoxon: $p < 0.05$) which would mean that a haptic feedback not consistent with the video sequence decreases the QoE. Interestingly the haptic feedback provided by the *Semantic* model is not significantly different from the *None* condition ($S_S^{All} = 0.51 \approx S_N^{All} = 0.5$, Wilcoxon: $p > 0.05$). But this *a priori* equality requires a deeper analysis.

The scores for each model and for each sequence are depicted in Figure 7. The tendency observed previously is still valid: the score for *Cinematic* model is higher than *None* which is higher than *Random*. Except for the Vertigo sequence where the *Cinematic* model is not applicable in the sense that it provides the same feedback as the *None* condition. Scores for the *Semantic* and *None* conditions are different though. Haptic feedback from the *Semantic* model provides a higher QoE for the Vertigo, Arcing and Tilting sequences (Wilcoxon: $p < 0.05$). For the Tilting sequence, it is not significantly different from the *Cinematic* condition ($S_S^{Ti} = 0.73 \approx S_C^{Ti} = 0.75$, Wilcoxon: $p > 0.05$). Otherwise the score is lower than the *None* conditions for the other sequences (Wilcoxon: $p < 0.05$).

# 6 Discussion

Our results suggest that haptic feedback related to camera effects improves the quality of video viewing experience. Besides, the haptic feedback has to be well-designed otherwise the QoE is decreased such as with the *Random* feedback. Haptic effects directly related to the camera movements (i.e. computed from *Cinematic* model) seem relevant for all sequences while a metaphoric approach manually created with strong hypothesis (i.e. *Semantic* model) is successful for particular cases.

In this study the *Semantic* model was preferred to the *None* condition for three sequences out of seven. The metaphors for these sequences (Arcing, Tilting and Vertigo) were rendered as linear movements while the others were non linear. As the movements of the camera were also linear, we think that the dynamics between the visual stimulus and the haptic feedback is important for users. A huge difference would lead to a feeling of de-synchronization. This point may be confirmed by the results of our previous studies [3, 4]: the *Random* feedback was preferred to the *None* feedback with first-person point-of-view video sequences of dynamics events (horse ride, bike ride, car drive). In this case, this feedback was not perceived as totally desynchronized.

We have also observed that the direction of the movement of the actuators seems to less impact the QoE. For the Tilting sequence the output of the *Cinematic* model is a backward rotation while the output of the *Semantic* model is a downward movement of all actuators. Directions are different but both were equally appreciated.

Interestingly the metaphors are recognized by several participants. They reported in the post-test questionnaire something similar to a “foot walk” or a “crab walk” for the Zoom-In and Traveling sequences. Some of them even recognized the “flying away” metaphor for the Crane Shot sequence. This would mean that the semantics associated to these effect is understood. However they reported that these haptic effects are not easy to interpret because of the lack of context. According to them, this would work for first-person point-of-view videos or video games where the audience can assume being the main character. Moreover cinematographic effects like the Dutch Angle are designed to be uncomfortable for the user, so the related haptic metaphors are not inclined to be chosen over a *None* feedback.

From these observations we would say that (1) the visual feedback determines the context (dominance of visual over haptic modality). Then (2) the haptic feedback may be perceived as coherent if its dynamics is similar to the visual motion, but (3) it seems unnecessary to follow the same direction. Deeper investigations are required to determine precise thresholds of the haptic perception in multimedia context, but these results represent a first step in the provision of guidelines for haptic designers.

# 7 Conclusions

We propose a taxonomy of haptic effects for audiovisual and introduce the notion of *Haptic Cinematography*. In this context, a new kind of haptic effects based on cinematographic camera motions is presented. These cinematographic techniques are extensively used by movie makers to create emotion or ambiance. We believe that haptic feedback can underline these techniques and enhance the video viewing experience. We propose two models to render such haptic effects: the *Cinematic* model where parameters of the camera are directly used to make users feel the movement of the camera, and the *Semantic* model based on metaphors reproducing the meaning usually conveyed by this technique.

A user study was conducted to evaluate the relevance of this approach. Results showed that the haptic feedback computed with our models improves the quality of experience while a random haptic feedback decreases it. More precisely the *Cinematic* model is well adapted to all sequences while the *Semantic* model seems effective for specific conditions. In addition, effects should be designed according to the dynamics of the camera movement but the direction of the haptic and camera motions may be different. Besides, meaning could be conveyed by haptic feedback but its understanding seems to be influenced by the context of the video.

Future work will be dedicated to a deeper analysis of these new haptic effects based on cinematography. Longer sequences with a richer content will serve to understand more precisely the influence of haptic feedback. Furthermore the combination of sequences and haptic effects, diegetic and non-diegetic, needs to be studied.

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Figure 2: Screenshots of the sequences (from top to bottom: Crane Shot, Arcing, Dutch Angle, Tilting, Traveling, Vertigo and Zoom-in). The viewpoint displayed at the beginning of the sequence is modified by the movement of the camera (from left to right pictures).

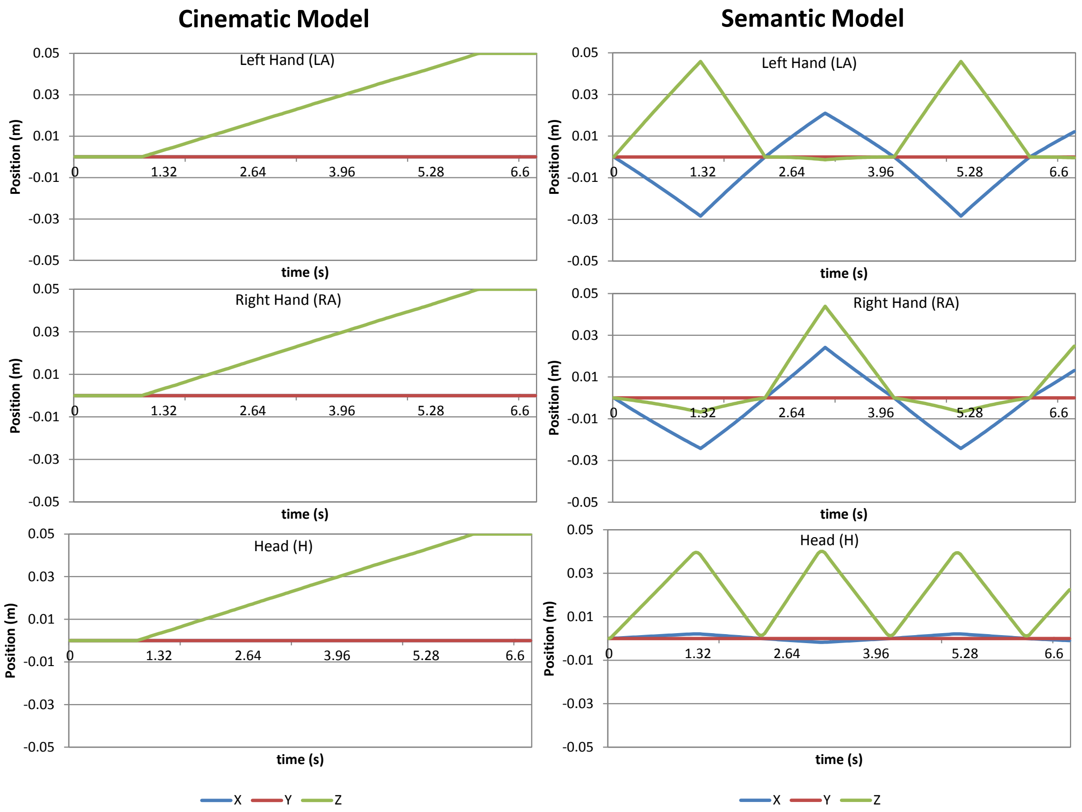

Figure 4: Output of the models for the Zoom-in sequence (position of each actuator).

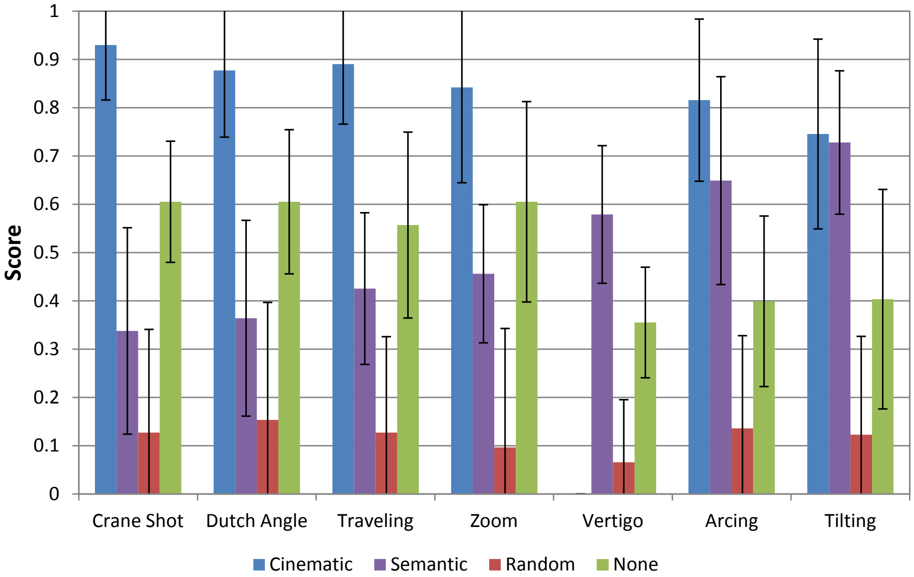

Figure 7: Detailed results for all sequences. Score for *Semantic* model is higher than the score for *None* for Vertigo, Arcing and Tilting sequences.