Estimation of Visually Induced Motion Sickness from Velocity Component of Moving Image

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Abstract. The purpose of the study is to examine whether the effects of global motion, (GM), on visually induced motion sickness, (VIMS), found with visual stimulus consisting of simple global motion will be applied to the effects of moving images including combination of global motion on VIMS. We, previously, found that velocity, but not temporal frequency component, of GM dominates subjective scores related to VIMS in the experiments presenting simple GM. To achieve the purpose, I made a model to estimate discomfort level of a standard observer during watching a moving image. The model, at the beginning, analyses GM included in the movie; and then, the time-series of velocity data in each element of analyzed GM is compared with the characteristics of simple GM on VIMS for estimating discomfort level. The validity of the model was examined by comparing the estimated discomfort level and actually measured average discomfort level using identical video movie which rather easily inducing VIMS. As a result, the model well estimates the values of subjective score actually measured during observers watching video movies.

1 Introduction

Because of recent evolution of moving image technology, we can enjoy, communicate with, and learn from a variety of real and dynamic moving images. However, we may sometimes suffer from motion-sickness-like symptoms. The symptoms that are obtained when people are watching moving images are called visually induced motion sickness, or VIMS. Actual incident of VIMS was reported by news media in Japan in 2003, in which 36 students of 294 who watched a 20-minutes movie displayed on a large screen were treated at a hospital for a symptom of VIMS [2]. The cause is supposed to be frequent visual motion included in the footages, which was induced by jaggy and dynamic motion of handheld video camera.

There are many factors that possibly affect VIMS. As Lo and So [1] reported, the factors may be categorized in the following three: (i) how moving image is presented, (ii) who watches moving image, and (iii) what is presented as moving image. Among the factors, the trigger of VIMS can be visual motion, especially global motion or optic flow, which belongs to the item (iii) above. The literature actually reported effects of image rotation along each of the three axes, yaw, pitch and roll, on visually

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induced motion sickness [1, 3, 4, 5]. They reported that: (i) visual roll motion can be the most effective and visual yaw motion can be the least effective, and (ii) a certain range of rotational velocity is effective for VIMS. Moreover, our recent data indicated that the dynamic visual motion can affect temporal variations of subjective discomfort ratings (Ujike, 2007), which can be well associated with VIMS.

The present study investigates whether what we have found about VIMS with simple GM can be applied to discomfort induced by moving images, such as movies. In another word, I examined how global motion velocity affect VIMS from actual moving images. To do this, I developed and examined the validity of a model estimating time-varying discomfort level based on velocity components of GM.

2 Procedures

2.1 Model Development

As a tool to examine how global motion velocity affect VIMS in actual moving images, I tried to find out a mathematical function that connects camera motion velocity of a movie and discomfort subjective ratings that are experimentally obtained with the movie. For the camera motion, we use the term pan, tilt, roll, which correspond to yaw, pitch, roll in global motion, respectively.

To investigate the mathematical function of the model, I used a movie produced by computer graphics, which includes the identical camera motion of a movie provoking an incident of VIMS in Japan, 2003. Input of the model is the camera motion velocity, which can be obtained by analyses of local motion vector (LMV) and global motion vector (GMV) of the movie. Output of the model will be fitted to subjective discomfort rating, which is experimentally obtained every one minute during observer watching a video movie.

As a first step, in this study, instead of using camera motion velocity, we used video frame count that contains camera motion velocity included in the range of provocative to VIMS.

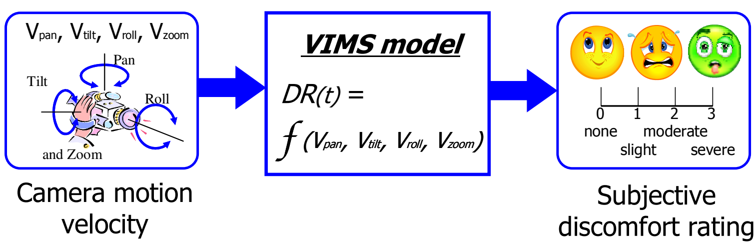

Fig. 1. A model connecting camera motion velocity as input and subjective discomfort rating as output

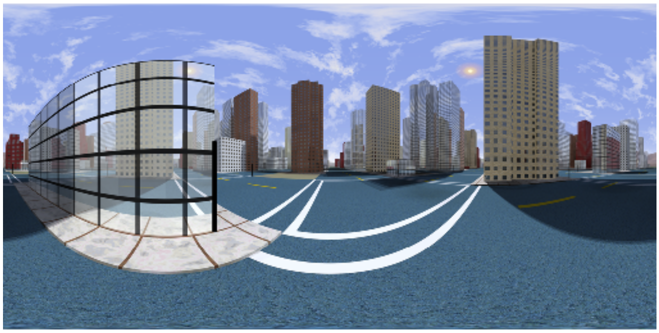

Fig. 2. City scene image presented to observer. The image was textured to inside wall of a sphere, at which center a virtual camera was set to make a movie image. The camera motion applied to the scene is shown in Fig. 3.

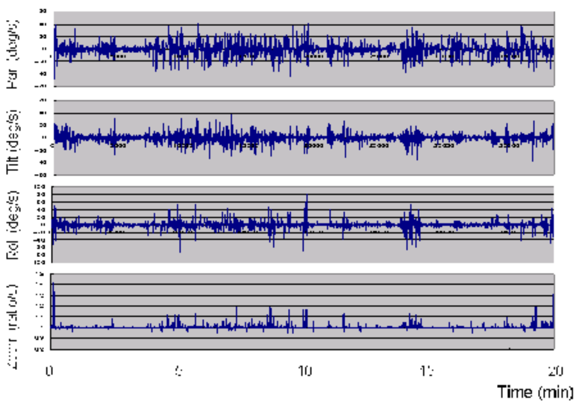

Fig. 3. Camera motion included in the moving image used in the study. The camera motion originated from the global motion analyzed from the movie of the incident in Japan in 2003.

2.2 Moving Image and Its Estimated Camera Motion

A sample moving image was produced for obtaining the input and output of the model. The moving image was a 20-minutes video footages that was made as computer graphics, (CG), movie of virtually produced city scene (Fig. 2). The camera motion in the CG movie was basically reproduced based on the camera motion estimated in the video movie that induced the incident in Japan in 2003. The camera motion velocity as input of the model is shown in Fig. 3.

Based on the effects of simple GM on VIMS found previous basic researches, number of frames that include camera motion velocity within the range provocative to VIMS was obtained and shown in Fig. 4. From this graph, large number of frames appeares at around 7 min and 16 min.

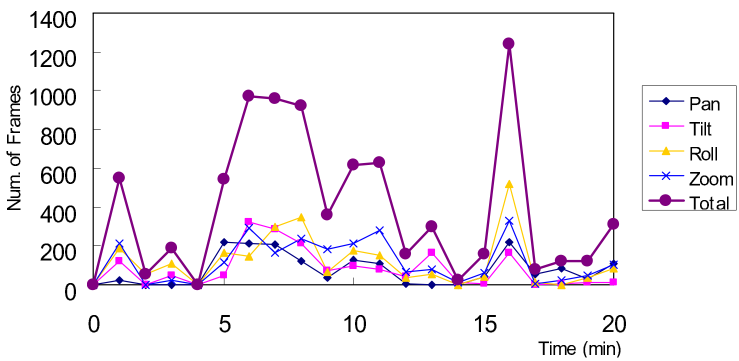

Fig. 4. Number of frames that include camera motion velocity within the range provocative to VIMS found by basic researches

2.3 Measurements of Subjective Discomfort Rating

The visual stimulus was video image that was comprised of five-minutes gray image, 20-minutes video footage described in the former section, and another two-minutes gray image, which were presented in this order. Four different small experimental booths were set up side by side; each of the booths was mostly enclosed by blackout curtain, was set up with a LC display, the chin-, head- and arm-rests, with a viewing distance of 1.0 m. There were two different size of the LC display, 20 inch (or 22.7 x 17.0 deg) and 37 inch (or 34.1 x 25.9 deg). The height of the LC display was adjusted so that the center of the display was the same as vantage point of observers. The experimental room was light-proofed, and the light other than the display was turn off during the experiment.

On one of the armrest, a response box was fixed. The response box has a button and a four-way joystick. The button was pressed when a small red dot was appeared for a short period on a movie image, in order to keep the observers eyes on the display screen. The joystick was used for observers to evaluate discomfort in a four point scale.

Thirty-three adults, aged 19-52 years (mean: 36.2, SD: 8.7; 24 females and 9 males), participated in the study as observers, after giving their informed written consent in accordance with the Helsinki Declaration, and were free to withdraw at any time during the experiment. The study was approved by the Ethics Committee of the National Institute of Advanced Industrial Science and Technology. The observers were naïve as to the purpose of the experiments, and had normal or collected-to-normal visual acuity.

Each experimental session started with asking observers to do Simulator Sickness Questionnaire, and then, observers fix their heads at chin- and head-rests, and their arms on armrests. They watched the video movie for 27 minutes; during this time, observers were asked, every one minute, to report about one of SSQ score, “General discomfort” in four alternatives: “None,” “Slight,” “Moderate,” and “Severe”; they report the score using the four-way joystick. The observers also need to respond by pressing the button on the response box when a small red dot was appeared for a short

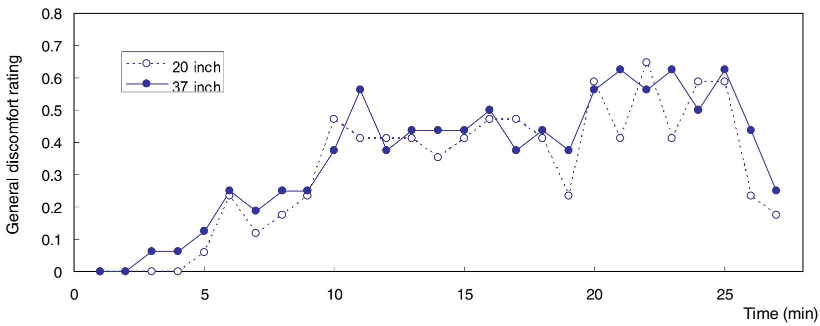

Fig. 5. Averaged discomfort rating obtained in the experiment

period on a movie image; the position and time (three times every minute) of the appearance of the was randomized. Just after finishing watching the video movie, they started, again, SSQ, and then they did it another three times every 15 minutes.

The measurement results are shown in Fig. 5, in which averaged value of general discomfort ratings are plotted against time.

3 Analyses for Modeling

When the frame count based on camera motion velocity data in Fig. 4 and the subjective discomfort rating in Fig. 5, the following two can be pointed out:

1. When the frame count increases, the discomfort rating increases.
2. The rating gradually increases with time, despite no-increment of the frame count.

These points may indicate that there are two different time components of development of VIMS. The first one is transient component, and the second one is accumulated component.

To develop a model estimating discomfort level, I examined whether subjective discomfort rating can be reproduced by weighted average of the frame count data. Considering the two possible components described above, I adopted the followingg mathematical expression. That is, the discomfort rating at time tn:

$$DR(t_n) = FC(t_n) * w_n + FC(t_{n-1}) * w_{n-1} + FC(t_{n-2}) * w_{n-2} + \cdots$$

while,

$$FC(t_n) : \text{ Frame count at time } t_n$$

The function was obtained by multiple regression analysis. Because of the collinearity problem (condition index <5.0), we adopted one present and three previous values of frame count.

$$DR(t_n) = \sum_n (FC\ (t_n) *w_n + FC(t_{n-1}) *w_{n-1} + \cdots + FC(t_{n-3}) *w_{n-3})$$

$$W_n = 0.319,\ W_{n-1} = 0.164,\ W_{n-2} = 0.068,\ W_{n-3} = 0.139$$

The difference between the discomfort ratings and the regression has linear trend: (Difference) = 16.361xTime - 171.86.

This trend can not be simply explained by the sum of the weighted average of frame count values. This may represent the accumulation effect: after some exposure to visual motion, the rating becomes larger for the same range of camera motion velocity. Then, I combined the multiple-regression function obtained above and the residual liner trend.

Therefore, the discomfort rating can be formulated as follows:

$$DR(t_n) = \sum_n (FC\ (t_n) *w_n + FC(t_{n-1}) *w_{n-1} + \cdots + FC(t_{n-3}) *w_{n-3} + A*t_n) + B$$

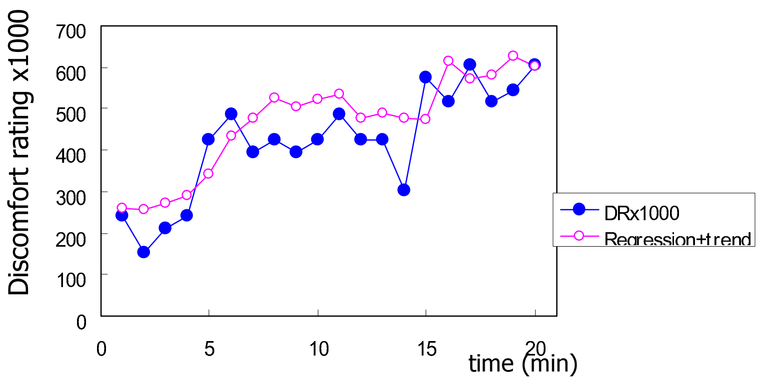

Fig. 6. Comparement of the Discomfort ratings and estimated scores obtained by the model

4 Summary

With multiple regression of camera motion velocity data to subjective discomfort rating, I have developed the model estimating valid values of discomfort level caused by moving images. Moreover, during the development of the model, I found two different temporal components of discomfort related to VIMS.

In the study, discomfort induced by moving images can be mostly determined by the velocity and time period of GM in a moving image.

Acknowledgement

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