Study on inspecting VR Motion Sickness inducing factors

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***Abstract*—There is a lot of research going on about VR technology in recent years, and there is also interest from global companies. However, most of users suffer from the difficulties in use of VR contents due to motion sickness. In this paper, definition, causes and solutions for the motion sickness will be investigated. To resolve the motion sickness problem, this paper will propose the test system which allows users to prevent motion sickness at the time when VR contents are produced and take a close look at the architecture of the system.**

***Keywords*—Virtual Reality, Human Factor, VR, HMD, Motion Scikness**

I. INTRODUCTION

The production of VR contents using HMD (Head Mount Display) has been actively performed all over the world. The VR is expanding beyond the existing CG-based content to the extreme reality experience contents service utilizing experience interaction, virtual reality, and the like. As the market that allows general people to record and produce their own contents by themselves is being organized as well as games and movies, huge amount of contents are continuously being produced. However, in case of VR contents based on HMD, users could encounter diverse problems while using them. First of all, VR motion sickness is considered to the most serious problem. For continuing success of HMD-based VR contents market, prevention and solution for sickness issue are critically important. Traditional studies on 3D have worked on human factors which are necessary to avoid sickness. Since both of 3D video and VR video are commonly based on stereo video, it is possible to identify factors that cause motion sickness in HMD-used VR contents based on 3D Human Factors.

This study aims at specifying factors that cause HMD-based VR motion sickness. Base on that, this study aims at proposing the system that can evaluate the degree of risk of motion sickness for VR contents and prevent the motion sickness.

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This study aims at specifying factors that cause HMD-based VR Motion Sickness. Also, basically the VR content is implemented by using a 'Stereo 360 Degree Image' material. In order to examine the contents of various VR devices, we propose a system that can prevent and check the risk of motion sickness of Stereo 360 Degree Image based Contents by using image processing technology.

II. MOTION SICKNESS IN VR

A. Definition of VR Motion Sickness

Generally people sense the gravity and horizontal/ vertical rotation using vestibular system of the inner ear consisting of otolith organs and semicircular canal.

The generally accepted theory explains that the motion sickness is caused by disparity between information on gravity and rotation coming from vestibule and visual information coming from eyes. Aside from that, there is another opinion that tactility information felt by sole might additionally affect the motion sickness[1].

While people ride on cars or airplanes, their eyes see the inside of cars or airplanes but their bodies are actually moving. Due to this discrepancy, people mostly feel nausea or vomiting[2].

The situation in which the motion sickness arises can be divided into two categories. First case is that there is not sufficient visual information while sensory information coming from vestibular system keeps changing. An example of this case is a general car sick as mentioned above[3]. Second case is that there are not sufficient updates occurring about sensory information coming from vestibular system while visual information keeps changing. An example of this case is the situation where a player moves fast in VR contents while the user is wearing HMD[1][4]. In this case, although visual information keeps changing, the user's actual body is sitting

down or standing up without movement, which causes disparity of information.

As discussed above, the motion sickness that arises while the user is experiencing VR contents with wearing HMD is called VR motion sickness. This emerges as one of the most challenging problems that could block the way to extend and strengthen VR market and VR contents production.

B. How to resolve VR Motion Sickness

As discussed above, the cause of VR motion sickness is disparity between visual information that keeps changing and information on sense of balance that does not change. To resolve this problem, there can be two approaches. First approach is to alleviate the strength of sense coming from vestibular system. Second approach is to reconcile visual information with equilibrioception information as much as possible.

Among two approaches, the first one to alleviate sensibility of vestibule is being widely used in cure for a general car sick. By attaching or taking medicine that will paralyse vestibular system, this approach attempts to minimize the sensibility which accepts sensory information through vestibular system. There are dedicated VR products in the market, for example, Dramamine and VIRMO. Prior to using HMD devices, taking medicine that can alleviate sensibility of vestibular system results to decrease of causing rate of motion sickness. However, this is just temporary solution because it causes worries or concerns due to medicine-taking and potential side effect that might happen.

The second approach is further divided into three sub-categories. Since the problem is caused by disparity of two senses, this approach attempts to make changes to sense or alleviate to make those two senses identical as much as possible.

- Firstly, there is an approach to inject information at corresponding timing with visual organs. Current VR market makes its most effort on this way. When the users change their view by rotating their heads with wearing HMD, the corresponding screen will show up without delay in this scheme. Due to the hardware capability constraints, approximately 20ms of latency occurs between rotation of head and update of view at middle to high-end devices. The latency can be the biggest reason to cause the motion sickness. To avoid the occurrence of motion sickness, latency ultimately should reduce to 0ms. While several graphic technology companies such as AMD and Nvidia focus on developing VR SDK, technological advancement from the perspective of hardware such as HMD is most highly related to this issue.
- Secondly, there is an approach to inject information at corresponding timing with vestibular system. Though there are not many cases taking this approach, related works have been consistently carried out. The most representative case is GVS(Galvanic Vestibular Stimulation) which breaks the balance of the target toward the desired direction by supplying current to user's vestibular system to stimulate it. In case of VR contents, this approach is used to resolve the disparity by stimulating vestibular system of the player to break the physical balance forcibly when the player rotates visually or loses balance. Currently, Entrim 4D is under development by Samsung adopting this approach.
- Lastly, there is an approach to minimize gap between two information or to change the visual information for enabling prediction. This approach solely relies on ability of the planner since it depends on contents planning and know-how. When VR contents are used and the unpredictable situation is encountered, motion sickness the user feels can be maximized[5][6]. For example, if the user suddenly moves to the side or backward by some sudden shock, the user can feel considerably significant motion sickness caused by big disparity between vestibular system and sensory information due to drastic changes in visual information.

III. THE PROPOSED SYSTEM

A. Necessity of the system

In previous chapter, the approaches to prevent VR motion sickness are described. Ultimate solution would be accomplished if the hardware technology would satisfy 0ms of latency, 8K of resolution and an increased FPS(Frame per second) up to 90-120 FPS. Then VR motion sickness mostly will disappear. However, it will take considerable time to satisfy such an ideal hardware, while expectations and demands for VR market are now growing fast.

Therefore the requirements for the system enabling to minimize VR motion sickness from the perspective of the planning and software are essential. In spite of this, factors affecting VR motion sickness rather than hardware's perspective have not been identified yet. In reality, however, production of good quality of contents heavily rely on experiences of planner or developer. Additionally, most of VR motion sickness control programs so far evaluate the risk of motion sickness for contents by collecting the subjective data

on dizziness felt by test subjects. Thus it takes high cost and time to do the test, and it lacks the objectiveness.

B. System Overview

The proposed system is a system that evaluates the degree of risk of motion sickness and generates proper warning making use of VR stereo 360° image as source no matter what HMD device is used in the VR development environment.

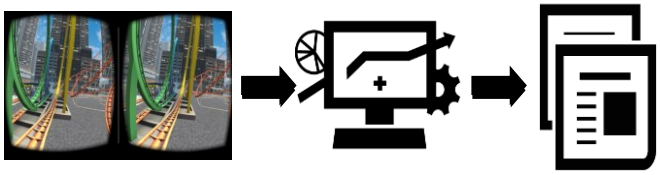

Figure 1. VR MOTION SICKNESS TEST SYSTEM OVERVIEW

For evaluating the motion sickness risk for the contents, the system receives VR stereo 360° image as input, evaluates the degree of risk at different VR motion sickness causing factors with help of image processing technology, and generates report about the risky frame and motion sickness causing factors if there is any factor whose risk exceeds a threshold. The user can easily recognize what time period and which part of the contents may involve motion sickness. As the last step, this system generates VR motion sickness risk report containing details about the frame that may cause motion sickness and average degree of risk for entire image.

C. Establish VR Motion Sickness causing factors

To develop the system as proposed in the previous section, it is necessary to establish which phenomenon cause motion sickness in VR contents. The proposed system will focus on listing up the factors at which the degree of risk can be evaluated with use of image processing technology among other VR motion sickness causing factors that are not completely verified yet. Based on the causing factors, this system will evaluate the degree of risk by numbers.

Table 1 lists up VR motion sickness causing factors that will be considered in the proposed system.

Table 1. VR MOTION SICKNESS CAUSING FACTORS

Causing factors	*Detailed Description*
Considerable size of time gap (absolute)	Disparity of object in the image is too big or too tiny
Considerable size of time gap (relative)	Time gap of object in the image becomes too big or too small in short time period.
Fast movement of Object	Major object with large volume moves too fast.
Fast movement at camera viewpoint	Viewpoint of camera changes too fast.
Frequent and repetitive movement of camera	Camera Shaking phenomenon. Like the camera moving fast and frequently in a car which runs on the road, camera shakes a lot repeatedly and frequently.
Sudden and drastic movement of camera to the side and backward	Rather than forward, camera moves suddenly and swiftly backward or to the side.

D. Acquisition of Disparity-map

For Binocular Disparity among the VR Motion Sickness inducing factors, it should be calculated from the left eye-right eye image(Stereo Image). In this case, Disparity-Map calculation method is very important for motion sickness test because reliability of Disparity Value is determined according to the accuracy of Disparity-Map.

In this paper, Disparity -Map is obtained by using 'SGBM Block Mathing Algorithm' for Disparity-map acquisition and accuracy is improved by 'Edge-Based Hole Filling' post-processing. Using the obtained Disparity-Map, we can calculate ‘VR Motion Sickness inducing factor’ related to the disparity in Table.1.

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$$E(D)=\sum_{p}\left(C(p,D_p)+\sum_{q\in N_p}P_1\left[|D_p-D_q|=1\right]+\sum_{q\in N_p}P_2\left[|D_p-D_q|>1\right]\right) \quad (1)$$

(1) is the SGBM Algorithm. This algorithm (1) aims to minimize the following global energy function, E, for disparity image, D.

With P2≥P1, where E(D) is the energy for disparity image, D is p, q represent indices for pixels in the image. Np is the neighborhood of the pixel p. C(p, Dp) is the cost of pixel matching with disparity in Dp. P1 is the penalty passed by the user for a change in disparity values of 1 between neighboring pixels. P2 is the penalty passed by the user for a change in disparity values greater than 1 between neighboring pixels. I[.]

is the function which returns 1 if the argument is true and 0 otherwise.[7][8]

The minimized function produces a perfect disparity map with smoothing governed by parameters P1 and P2; however, minimizing the function for a 2D image space is an NP-complete problem. The semi-global matching function approximates the 2D minimization by performing multiple 1D, or linear, minimizations. The matching function aggregates costs on multiple paths which converge on the pixel under examination. Cost is computed for the disparity range specified by the minimum disparity and number of disparities parameters. By default, the matching algorithm aggregates costs for 5 directions. You can set the full dynamic programming parameter to true to force the algorithm to aggregate costs for 8 directions.

Figure 2. DISPARITY MAP ACQUISITION PROCESS
(UP : LEFT, RIGHT STEREO IMAGE,
DOWN : BEFORE-AFTER HOLE FILLING)

E. System architecture

The 360° Image based VR Motion Sickness Test System as proposed in this paper is designed as below to evaluate the degree of risk for VR motion sickness.

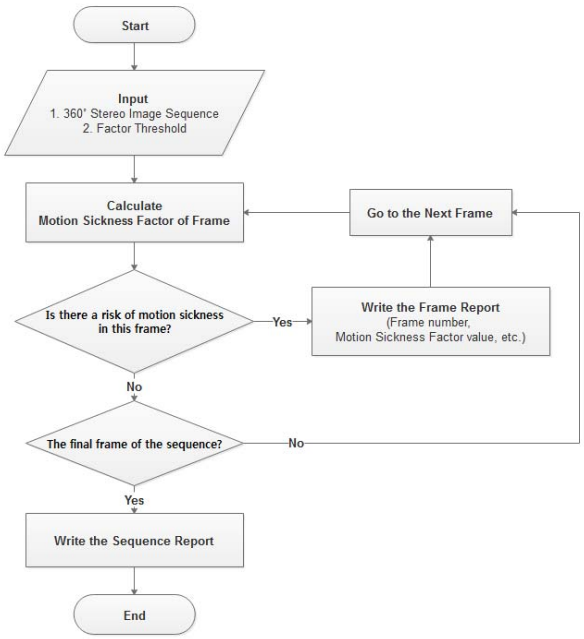

Figure 3. SYSTEM FLOWCHART

The system gets 360° Stereo Image Sequence and threshold values for VR motion sickness causing factors as user input. The system calculates motion sickness factor values for each frame sequentially starting from the first frame. If the system detects any frame having the motion sickness value that is higher than threshold, it reports the information about the frame and proceeds to next frame. In case of investigating the degree of risk of motion sickness at each frame, the degree of risk at each factor will be examined based on image processing scheme in a parallel manner. Once all the frame of the sequences are completely investigated, the system will generate the final report and its operation will be terminated.

The system user edits motion sickness risk degree for the contents by referring both of the risky frames report and the final report.

IV. CONCLUSION

VR market is now growing fast day by day. HMD devices outstandingly lead by Oculus are now being diversified along with expansion of mobile devices market. Correspondingly, a wide variety of contents also are being released. In this study, the VR 360° Stereo Image-based system is proposed to resolve the big challenge of motion sickness no matter what the contents environments are taken. The proposed system is expected to prevent potential problems that might cause motion sickness at the time of production of VR contents, which will

significantly contribute to improving the completeness of the contents.

There are rare studies conducted so far on VR motion sickness field. Except for hardware issues, the perspectives regarding contents have not been investigated yet. Future study will aim at verifying the motion sickness causing factors considered in this study through clinical test. Based on that, future study will work on enhancing completeness of this study by supplementing additional causes other than the causes identified in this study.

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