논문 2011-48SD-10-4

사용자 불편함 개선을 위한 입체 영상 피로도 지수 측정

(Measurement of Level of Stereoscopic Visual Fatigue for User Discomfort Improvement)

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요 약

최근 다양한 3D 콘텐츠가 개발됨에 따라, 극장이나 자택에서 3D 안경을 이용하는 사용자들이 증가하고 있다. 하지만 입체 영상이 피로감을 발생시키기 때문에, 개발자들도 특히 어린이나 임산부 등에게는 장시간 시청을 지양할 것을 권고한다. 본 논문에서는 이러한 사용자 불편함을 개선하기 위해 디스페리티-맵의 히스토그램을 분석하여 영상 피로도 지수 측정을 제안하였다. 영상 피로도 지수 측정은 입체 영상의 피로도를 발생시키는 가장 기본적인 요인인 두 눈으로 보는 차이를 이용하였다. 이는 입체 영상을 생성하거나 보정, 또는 시청할 때 참조하여 사용자 불편함을 개선할 수 있다. 제안된 방법에서는 디스페리티-맵을 얻기 위해 실시간 처리에 적합한 Census 알고리즘을 사용하였다.

Abstract

As various 3D contents have been developed recently, number of users who use 3D glasses in the cinema or their house has increased. However, since a stereoscopic image causes visual fatigue, developers also advise children and pregnant against watching it for hours. In this paper, we proposed measurement of level of visual fatigue degree by analyzing histogram obtained from a disparity-map. We used binocular disparity approach which is a fundamental factor occurred by a stereoscopic image. This research can be used as an user discomfort improvement method by referring to a stereoscopic image producing and compensation. To obtain a disparity-map, our proposed method used a census algorithm which is suitable for real-time processing.

Keywords : visual fatigue, visual stress, measurement, stereoscopic image, real-time image processing

Ⅰ. INTRODUCTION

Recently, as various 3D contents have been developed, almost all of the users suffer from visual fatigue[1] when they watch a stereoscopic image for hours. Therefore, necessity of a stereoscopic image compensation is increasing for user discomfort improvement. For this reason, to measure the degree of stereoscopic visual fatigue, plenty of researches with various approaches to reduce visual fatigue have been studied vibrantly such as 1) the background, theories and observations of visual fatigue[2] and 2) the relationship between convergence eye movement and the accommodation function and basic visual perception of stereoscopic images based on binocular fusion[3]. In this paper, our approach was motivated by a fundamental idea such that general users are acclimatized to 2D image. Based on this fact, we determined thresholds in a disparity-map histogram, and measured visual fatigue level by obtaining the sum of number of pixels in the positive and negative regions. We defined the positive region as a region

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접수일자: 2011년6월30일, 수정완료일: 2011년10월10일

close to a point where disparity is 0 and stereoscopic effect is minimum. On the other hand, the negative region is the remainder where disparity is high. Then we display visual fatigue level data to refer to image producing or compensating for user discomfort improvement.

The rest of paper is outlined as follow. We introduce general human visual system in Section Ⅱ. Our proposed measurement method will be presented in Section Ⅲ. Experimental results will be given in Section Ⅳ, and finally, in Section Ⅴ, we draw the conclusion.

Ⅱ. HUMAN VISUAL SYSTEM

Human visual system uses two eyes to recognize objects and their depth using difference of field of view in each eye. As shown in fig. 1, the creation principle of a stereoscopic image which has 3D effect on the 2D screen follows the human visual system. First, we create two different images which have different field of view. The disparity between the object on the left and the right images depend on depth of the object. Second, we configure stereoscopic system such that the left eye only sees the left scene, and the right eye only sees the right scene. Finally, we synthesize the difference of field of view. Therefore, since actual computation is operated in the human brain, which is the source of visual fatigue,

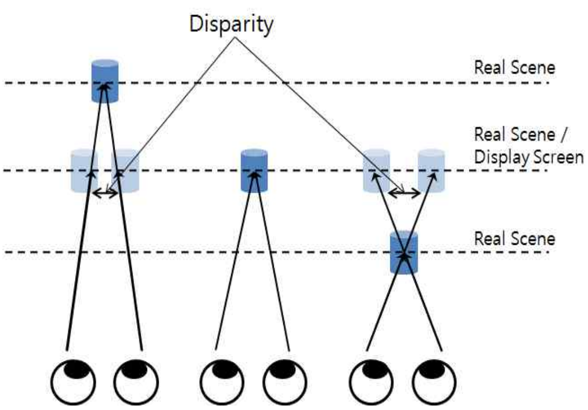


그림 1. 인간 시각계
Fig. 1. HUMAN VISUAL SYSTEM.

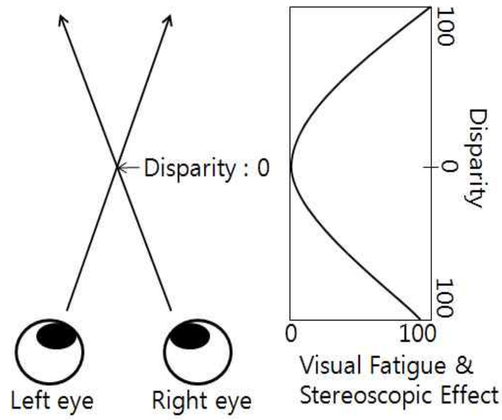


그림 2. 인간 시각계에서의 거리에 따른 사용자 피로도 관계(X축과 Y축의 값은 상대적인 크기를 표시)
Fig. 2. Visual Fatigue in Human Visual System (Values in X and Y axis are relative numbers).

viewing time and disparity value of stereoscopic image determine degree of visual fatigue. Fig. 2 shows visual fatigue is dependant on disparity.

We used the point where disparity is 0 as a fiducial point and configure two thresholds. Then we measured level of visual fatigue and compensate stereoscopic images for user discomfort improvement. We will explain detailed information in the following sections.

Ⅲ. PROPOSED MEASUREMENT METHOD

1. Disparity-map acquisition algorithm

To measure level of visual fatigue, first we need to obtain a disparity-map. There are three major disparity-map acquisition algorithms: 1) SSD[4](Sum of Squared Difference) which find matching points by comparison difference of squared value between a target pixel in the left image and pixels on the search range in the right image, 2) SAD[5](Sum of Absolute Difference) which is similar to SSD except for using absolute values and 3) census[6] which is a fast disparity-map acquisition algorithm and is suitable for real-time system and hardware architecture design.

In this paper, we adopted the census algorithm. Fig. 3 shows obtained disparity-map image using a census algorithm. However, the limitation of census is that there are noise and hole issues due to low accuracy. Therefore, we used image refinement[7] process to decrease noises and holes, and a filter to make images smoother.

그림 3. 디스페리티-맵 영상
Fig. 3. Disparity-map Image.

2. Histogram

After we obtained disparity-map, we calculated histogram. X-axis and Y-axis in the histogram represent disparity value and number of pixels at the disparity relatively. Fig. 4 shows an example of obtained histogram. Disparity values in the X-axis are from -105 to 105, and the center point is the same as the point where a disparity is 0 in the human visual system.

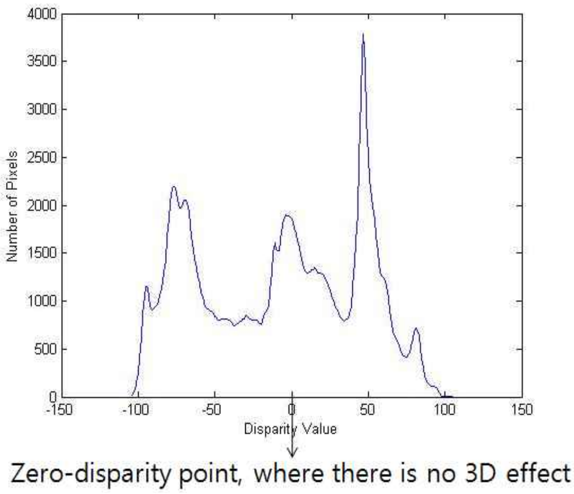


그림 4. 작성된 히스토그램의 예시
Fig. 4. Example of Histogram.

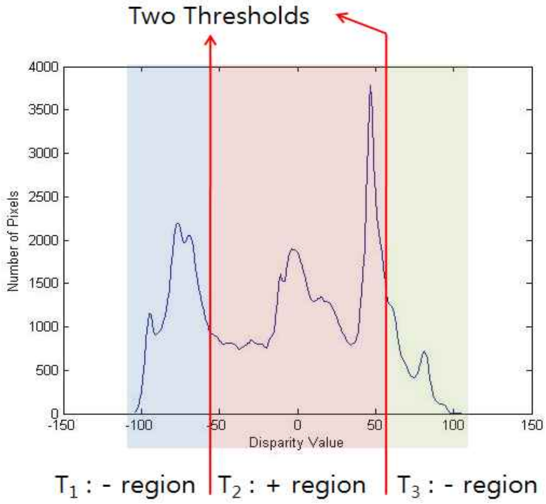


그림 5. 문턱값 설정 예시
Fig. 5. Example of Thresholds.

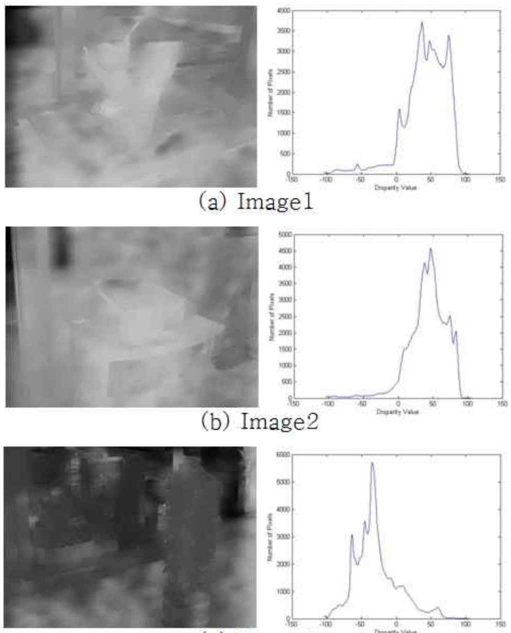
Basically, visual fatigue increases as a disparity value is far from zero-disparity point where there is no 3D effect. Based on this fact, as shown in Fig. 5, we configured three sets of two thresholds at each 40%, 50%, 60% points from zero-disparity point to compare, and each region labeled as T_1, T_2, T_3. The T_2 region which is close to zero-disparity point is a positive region. T_1, T_3 regions which are far from zero-disparity point are negative regions. Then we added up number of pixels in all regions with experimentally obtained weights. The reason why weight of T_1, T_3 regions are different is that the fatigue increase between the point where disparity is 0 and the user which is T_3 region is larger than T_1 region which is between the point where disparity is 0 and the background. And the weight of T_2 region is to obtain positive values. Then, to convert results into a percentage, we multiplied $\frac{100}{Total\ pixels}$. Accordingly, we modeled VFL(Visual Fatigue Level) function as shown in (1).

$$VFL = \frac{(1.25 \times \sum T_2 - 0.75 \times \sum T_1 - \sum T_3)}{Total\ number\ of\ pixels} \times 100 \quad (1)$$

VFL values obtained from (1) represent in inverse proportion. In other words, high VFL values have low visual fatigue, and low VFL values have high visual fatigue.

Ⅳ. EXPERIMENTAL RESULTS

To measure the level of visual fatigue, we calculated a disparity-map from a stereoscopic image, and analyze it to obtain a histogram. Fig. 6 shows results of disparity-maps from three different stereoscopic images and obtained histogram from each disparity-map.



(a) Image1

(b) Image2

(c) Image3

그림 6. 실험 영상의 디스페리티-맵과 히스토그램 결과
Fig. 6. Results of Disparity-map and Histogram.

We used number of pixels at the each disparity value from obtained histogram and measured VFL using the proposed method. Table1. shows experimental results included VFL values of each images and comparable result data obtained from ten observers participated in the MOS(Mean Opinion Score) test. Each observers marked grades for each images from 0 to 10 depend on degree of visual fatigue they obtained, and summed up to convert a total value into a percentage. As shown in Table1, a result with the threshold at the 60% has the most similarity to experiment results from participants which shows prominent reliability of results.

To use as reference data to compensate a stereoscopic image for user discomfort improvement, we could display obtained VFL as shown in Fig. 7.

표 1. 문턱값 설정에 따른 VFL 결과와 MOS 테스트 결과 비교.
Table 1. Comparison between VFL results with 3 thresholds and a MOS test result.

		Image 1	Image 2	Image 3
VFL values with three thresholds	40%	-2.62	-0.4	39
	50%	22	33	63
	60%	48	58	81
MOS Test		45	49	73

(a) Image1

(b) Image2

(c) Image3

그림 7. 사용자 피로도 레벨 표시 예시
Fig. 7. Examples of VFL display.

Ⅴ. CONCLUSION

In this paper, we measured VFL occurred by a stereoscopic image using several thresholds in the histogram obtained from a disparity-map. This VFL will be useful for user discomfort improvement by referring to image producing, or compensating result image using vergence control[8]. However, we only apply few factors, which is insufficient to model more reliable VFL function. Therefore, further research for defining more factors of stereoscopic visual fatigue will be needed in the future.

Acknowledgement

This research was supported by the National

Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (2010-0021489).

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