A METHOD TO EDIT MOVIES FOR A VISUAL SIMULATOR AND THE EFFECTS OF THE TORSIONAL MOTION OF HIGH-RISE BUILDINGS ON HUMAN PERCEPTION

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ABSTRACT

A study of the way in which humans visually perceive the motion of high-rise buildings was carried out. In our experiment, an edited movie was projected so that the subjects could observe the motion of the view from a window. The movie was edited by changing the speed of pictures that had been previously recorded by a video camera moving at a constant low velocity. In this way, a visual simulator created a movie replicating a cosine wave. The results of this experiment showed that visual perception is more sensitive than physical perception in the case of torsional motion. The threshold at which the subjects perceived the motion was determined as well.

INTRODUCTION

High-rise buildings are currently used as hotels and residences as well as offices and shops. When such buildings are used for residential purposes, the stay of accupants is considerably longer than when they are used for business purposes. Therefore, the problem of the habitability of architectural space has become more severe in recent years due to the multiplicity of uses of high-rise buildings. One of the problems caused by this diversification is the effect on visual perception of the torsional motion that takes place when residents look out the window[1)].

Therefore, in order to consider a new evaluation standard for torsional motion, the authors conducted studies about human visual perception thresholds based on results from translational motion. This paper describes the method used for editing the movie used in the experiment as well as the experiment's results.

DESCRIPTION OF THE VISUAL SIMULATOR

The following describes the way the movie was made and presented to the subjects.

(1) The view from the window was recorded by a video camera moving at constant low velocity from an elevated room in a high-rise building.

(2) After recording, the original pictures were converted into a movie, and the speed was changed by a computer (Apple: Macintosh 8100/100) at the laboratory.

(3) The movie, which was made using filming equipment, was projected from a video projector onto a transparent screen.

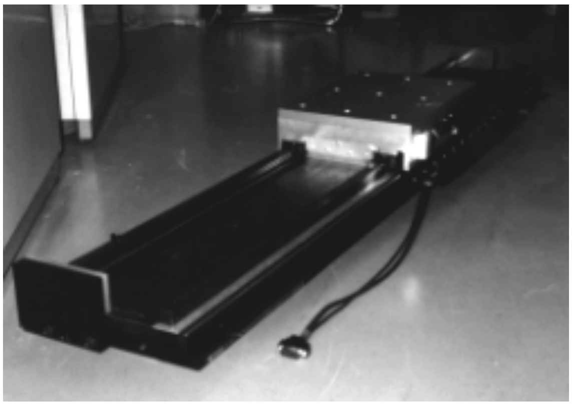
(4) For the experiment, the subjects watched the movie on a transparent screen resembling a window.

Recording system

Since the movement velocity of the video camera had to be very slow, the camera was set on a thrust motor[*1] (NSK: ML-B31150P009MC1BC) in the case of translational motion, and on a portable-type homing equatorial[*2] (Kenko: SKYMEMO NS) in the case of torsional motion.

[*1]The thrust motor has a pedestal that floats with magnetic force and, optionally, moves straight with precision, as shown in Photograph 1.

[*2]The portable-type homing equatorial has a pedestal that revolves at uniform velocity with precision, as shown in Photograph 2.



Photograph 1 Thrust motor

Photograph 2 Portable-type homing equatorial
and recording equipment

Procedure of taking pictures

The procedure for taking pictures is described below. *)indicates supplementary information

(1) The machinery and materials for taking pictures were carried to an elevated room of a high-rise building.

*)The studio was on the 54th floor of a high-rise building in Shinjyuku, Tokyo.

(2) A thrust motor or a portable-type homing equatorial was set up.

(3) The camera was fixed on it.

*)The camera used was a 3CCD camera (Panasonic:NV-x100).
*)In this study, the angle of depression was set up at 0deg, which means that the resident was looking at a distant place.

(4) The thrust motor or the portable-type homing equatorial was moved at the lowest possible speed, and pictures were taken.

*)In the translational motion, the moving velocity of the video camera was 1.80[mm/sec], which is the lowest velocity of the thrust motor, and the recording length was 700mm, which is the full length in movement.
*)In the torsional motion, the recording velocity was $4.17*10^{-3}$[deg/sec], namely 360[deg/day], and the recording range was 0.5deg.

Movie-editing system

The equipment used for editing included a computer (Apple: Macintosh 8100/100) and a periphery device (Radius: Video Vision System). Video Vision System is a video hardware interface that captures and plays back full-frame, full-motion composite, and S-video in either NTSC or PAL format. Figure 1 shows the system equipment. Figure 2 shows a flow chart describing the procedure of movie editing in simple.

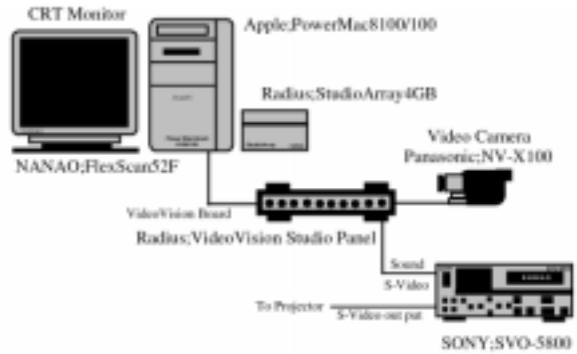


Figure 1 Movie-editing system

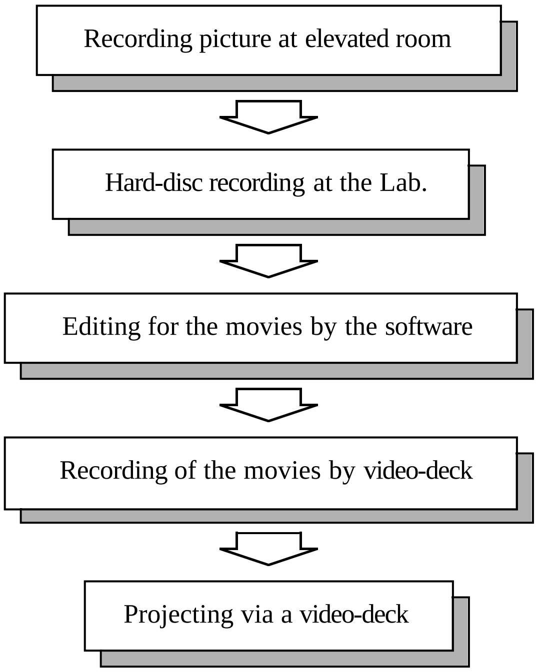


Figure 2 Procedure of movie-editing

Projecting system

Movies made using the filming equipment were projected from a video projector (SANYO: LP-9200N) via a video deck (SONY: SVO-5800) and reflected on a mirror to be displayed on a transparent screen, as shown in Figure 3.

Experimental room

The dimensions of the room were 2.33m x 2.33m; the window size was 0.8m x 0.6m. The angle of sight calculated in terms of the distance from subject to window was approximately 40deg. Figure 3 shows a plan of the experimental room.

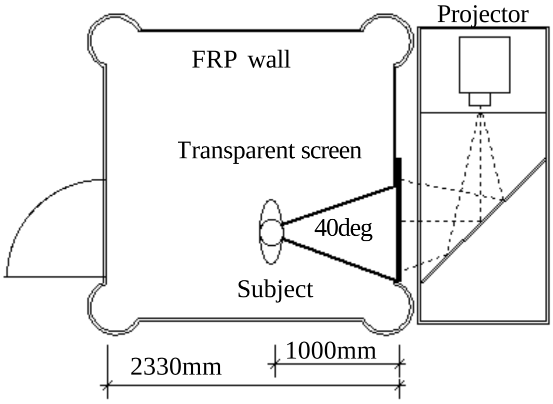


Figure 3 Plane of experimental room

PROCESS OF EDITING

Before editing, films were represented as a picture; after the editing, on the other hand, they were represented as a movie. The process of editing included distinguishing between the picture and the movie.

Unit time

Generally, VTR movies contain 30 frame structures to a second. Therefore, when movies are edited by software (Adobe Premiere ver4.0), the unit time is treated as 1/30[sec].

$$\Delta t = 1 / 30 \qquad \text{..........(1)}$$

where

Δt = unit time

Indication of the pictures' frame numbers

The position of the camera after the optional time is given by Formula (2):

$$y\ (t_n) = v \times t_n \qquad \text{..........(2)}$$

where

$y\ (t_n)$ = displacement after the optional time t_n
v = velocity of video camera (constant)
t_n = optional second

In addition, the frame number of the picture of this case is given by Formula (3), shown in Figure 4:

$$_rN_{tn} = t_n \ / \ \Delta t \qquad \text{..........(3)}$$

where

$_rN_{tn}$ = frame number of the recorded pictures

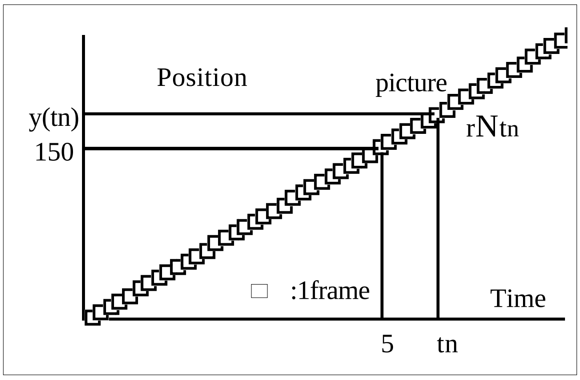


Figure 4 Frame number of recorded pictures

Substituting Formula (3) for Formula (2), we get formula (4). In this way, the displacement quantity of the recorded picture moving at uniform velocity with optional time can be shown by the frame number:

$$y\ (t_n) = v \times {}_rN_{tn} \times \Delta t \qquad \text{..........(4)}$$

First derivation of the formula to make movies

As for the cosine wave in harmonic motion shown in Figure 5, an optional displacement after the start of the movement is indicated by Formula (5):

$$y\ (t_m) = A \cos \{ (2\pi / T) \times t_m \} \qquad \text{..........(5)}$$

where

$y\ (t_m)$ = displacement after the start
A = amplitude (half)
T = period
t_m = optional second

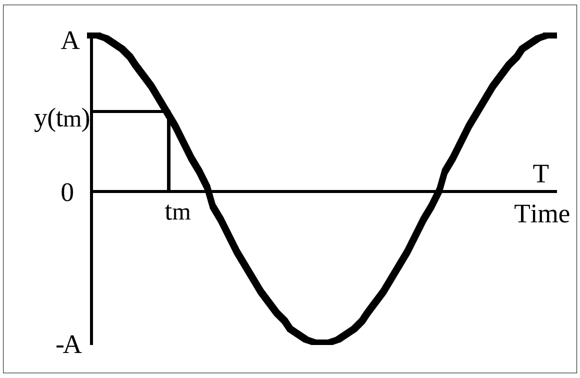


Figure 5 Wave form of cosine wave

Moreover, by numbering the frames of the movie in the order of $_pN_{t0}$, $_pN_{t1}$, $_pN_{t2}$,.....$_pN_{tm}$, and.......$_pN_{ti}$, as indicated in Figure 6, the frame number after the optional time is given by Formula (6'):

$$_pN_{tm} = t_m \ / \ \Delta t \qquad \text{.........(6')}$$

$t_m = {}_pN_{tm} \times \Delta t$ ....(6)

where

${}_pN_{tm}$ = frame number of the movie

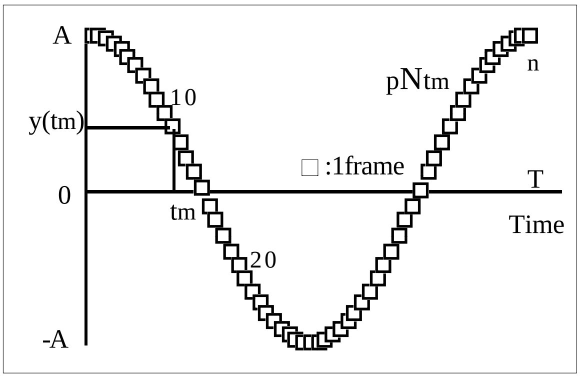


Figure 6 Frame number of the movie

Formula (7) is obtained by substituting Formula (6) for Formula (5):

$$y(t_m) = A \cos \{(2\pi / T) \times {}_pN_{tm} \times \Delta t\}$$

........(7)

Utilizing formula (4) and (7), ${}_rN_{tn}$ corresponded with ${}_pN_{tm}$ is calculated one by one, as indicated in Figure 7. And stringing these pictures, simulated movie is constructed. Therefore, formula (8) is presented and formula (9) related with formula (8) is conducted.

$$v \times {}_rN_{tn} \times \Delta t = A \cos (2\pi / T \times {}_pN_{tm} \times \Delta t)$$

........(8)

$${}_rN_{tn} = A / (v \times \Delta t) \times \cos (2\pi / T \times {}_pN_{tm} \times \Delta t)$$

........(9)

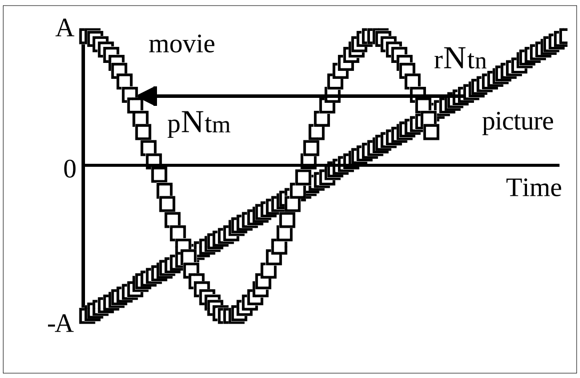


Figure 7 Relation between picture and movie regard with frame number

Namely, it becomes possible to identify the frame number of the movie corresponding to the picture frame.

Shift of the final formula for simulation movies

The following shift was introduced to simplify the editing process:

Starting point of the movement

In Formula (9), the range of the displacement is $-A \leq y(t_m) \leq A$. However, workability is higher when the camera is moved only one way. Therefore, the camera is displaced by +A and shifted to $0 \leq y(t_m) \leq 2A$, changing Formula (9) into Formula (10), as indicated in Figure 8:

$${}_rN_{tn} = A / (v \times \Delta t)\{1 + \cos (2\pi / T \times {}_pN_{tm} \times \Delta t)\}$$

........(10)

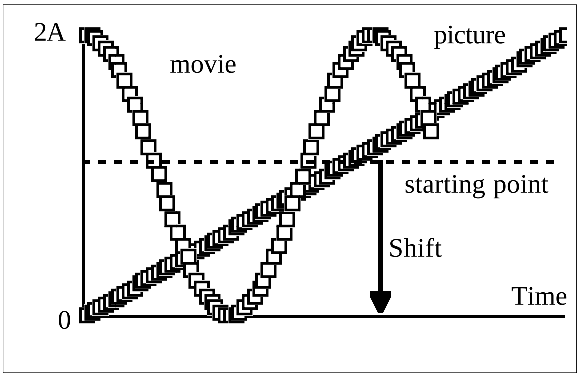


Figure 8 Shift of starting point

Reverse of the movie

In addition, ${}_rN_{tn}$ moves from 2 A to 0 at the first amplitude, but, during movie editing, workability is higher from 0 to 2 A. Therefore, a phase π is added to Formula 10, which is thus transformed into Formula 11, as indicated in Figure 9:

$${}_rN_{tn} = A / (v \times \Delta t) \times \{1 + \cos (2\pi / T \times {}_pN_{tm} \times \Delta t + \pi)\}$$

........(11)

Formula (11) is the final formula used to obtain the simulation movie from the pictures recorded in this study. An example of a torsional motion, A=0.048[deg], T=1.65[sec] is shown in Table 1 and Figure 10.

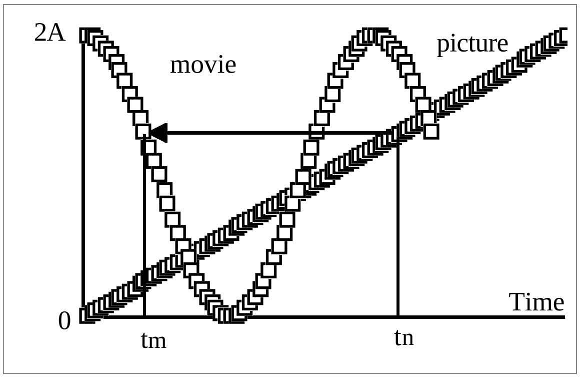


Figure 9 Reverse of the movie

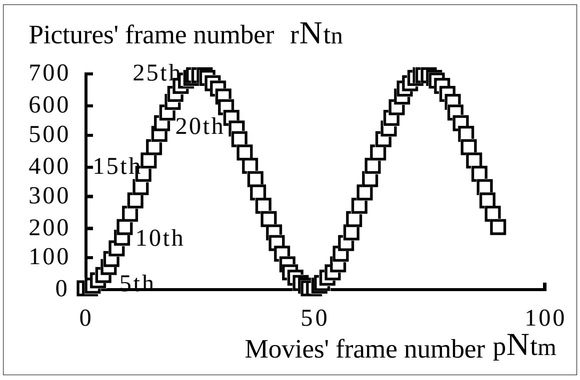


Figure 10 An example of the relation between picture and movie

Table 1 An example of the editing movie

$_pN_{tm}$	Displacement*)		$_rN_{tn}$	
	(9)**)	(11)***)		Round
0th	48.0	0.0	0.00	0
1st	47.6	0.4	2.79	3
2nd	46.5	1.5	11.11	11
3rd	44.6	3.4	24.83	25
4th	42.0	6.0	43.73	44
5th	38.7	9.3	67.51	68
6th	34.8	13.2	95.77	96
7th	30.3	17.7	128.07	128
8th	25.3	22.7	163.89	164
9th	20.0	28.0	202.65	203
10th	14.3	33.7	243.73	244
11th	8.4	39.6	286.47	286
12th	2.3	45.7	330.17	330
13th	-3.8	51.8	374.14	374
14th	-9.8	57.8	417.66	418
15th	-15.7	63.7	460.05	460
16th	-21.3	69.3	500.61	501
17th	-26.5	74.5	538.69	539
18th	-31.4	79.4	573.68	574
19th	-35.7	83.7	605.02	605
20th	-39.5	87.5	632.20	632
21st	-42.6	90.6	654.79	655
22nd	-45.1	93.1	672.42	672
23rd	-46.8	94.8	684.81	685
24th	-47.8	95.8	691.76	692
25th	-48.0	96.0	693.15	693

*) •10^{-3}deg, **)***) Formula

EXPERIMENT OF HUMAN PERCEPTION OF TORSIONAL MOTION

The authors report the experimental results of the human perception of torsional motion.

Experimentation

For the perception experiment, a questionnaire was used. When undergoing the experiment on visual perception, subjects only received visual information from the edited movies. When undergoing the experiment on physical perception, on the other hand, visual information was excluded and only physical information was given[2]. A scene from the movies used in this experiment is shown in Photograph 3. At each step, the time of the experiment was 2 minutes, and the exposure time was 1 minute; the time given for answering the questionnaire was 1 minute. To prevent weariness, subjects were given a 30-minutes rest after the 30-minute experiment. The order of the experiment conditions was chosen at random to prevent subjects from inferring a rule, which would nullify the experiment results.

Photograph 3 A scene of movie

Conditions applied in the experiments

Concerning the conditions for the experiment, a frequency of 0.152-0.606 [Hz] was set. The conditions for the visual perception experiment are shown in Table 2 below, and the conditions for the physical perception experiment are shown in Table 3.

Table 2 Experiment condition of visual perception

Frequency [Hz]	Amp. [deg]	Maximum Angular Velocity [mrad/s]
0.606	0.006	0.40
	0.009	0.60
	0.012	0.80
	0.018	1.20
	0.024	1.60
	0.048	3.20
0.303	0.012	0.40
	0.018	0.60
	0.024	0.80
	0.036	1.20
	0.048	1.60
	0.096	3.20
	0.192	3.20
0.202	0.018	0.40
	0.027	0.60
	0.036	0.80
	0.054	1.20
	0.072	1.60
	0.144	3.20
0.152	0.024	0.40
	0.036	0.60
	0.048	0.80
	0.072	1.20
	0.096	1.60

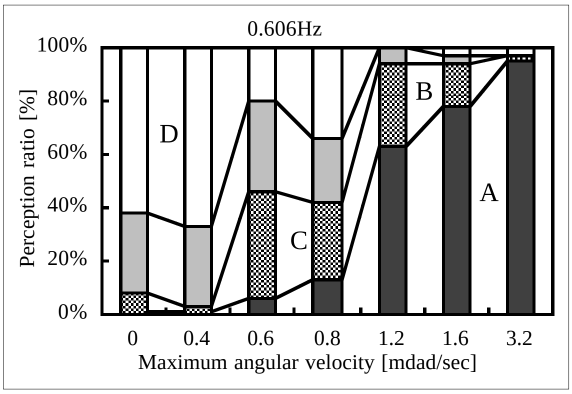
Table 3 Experiment condition of physical perception

Frequency [Hz]	Amp. [deg]	Maximum Angular Acc. [mrad/s^2]
0.606	0.1	25.309
	0.2	50.617
0.202	0.1	2.812
	0.2	5.624

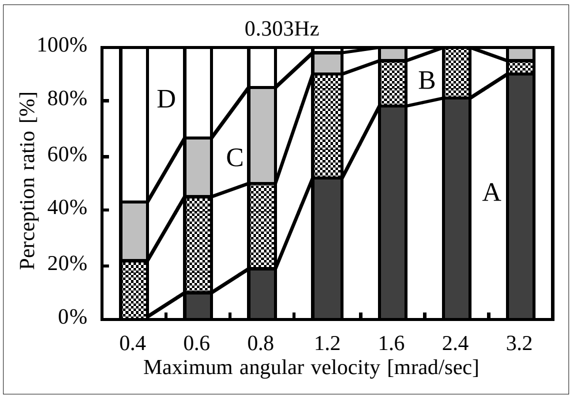
EXPERIMENT RESULTS

Visual Perception

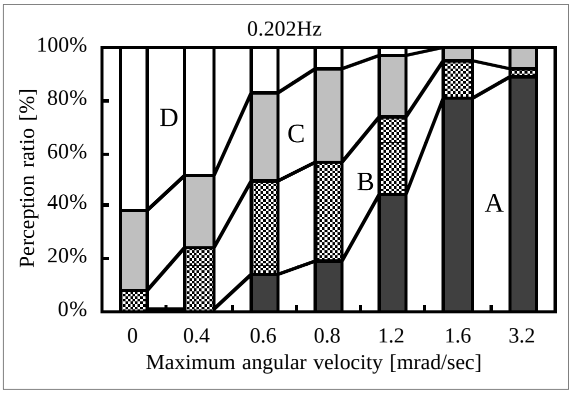
The subjects' visual perception responses to torsional motion are summarized in Figures 11(a) to (d). Of the predetermined response ratings, "clearly felt motion," level A in Figures 11, and "vaguely felt motion," level B, were considered to be evidence that the subjects had perceived motion. Weibull distribution curves were used to approximate levels of perception against peak angular velocity for the experiments of visual perception, as shown in Figure 12 and Table 4. Figure 12 shows the collected distribution curves with the same tendency toward every frequency. Consequently, measuring the degree of motion with a scale in angular velocity, the human perception threshold appears to be independent of the frequency, and the average perception threshold attains the same velocity. Table 5 shows the visual perception threshold obtained in the experiments.



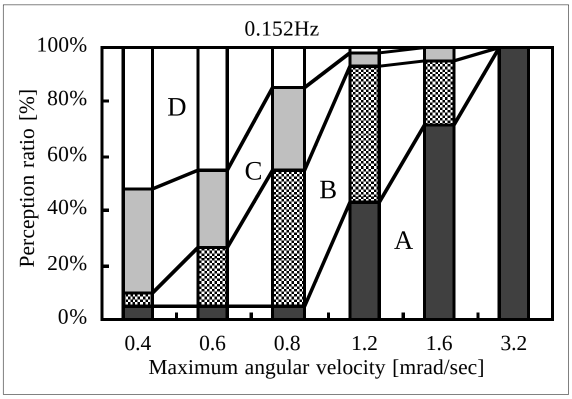
Figures 11 (a) Perceptional responses



Figures 11 (b) Perceptional responses



Figures 11 (c) Perceptional responses



Figures 11 (d) Perceptional responses

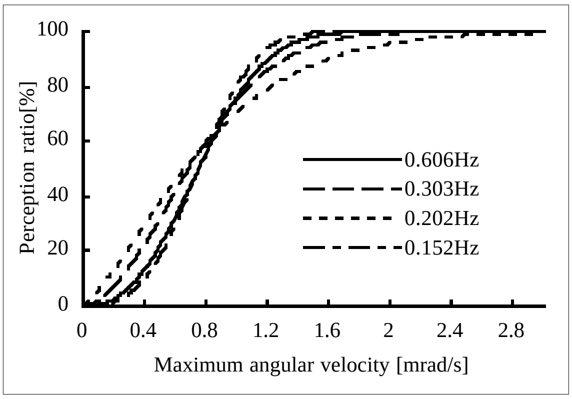


Figure 12 Results of torsional visual perception experiments at Weibull curves

Table 5 Perception threshold

	0.152Hz	0.202Hz	0.303Hz	0.606Hz
5%*	0.13mrad/s	0.08mrad/s	0.16mrad/s	0.10mrad/s
50%*	0.77mrad/s	0.68mrad/s	0.71mrad/s	0.77mrad/s
95%*	1.23mrad/s	1.92mrad/s	1.50mrad/s	1.34mrad/s

*Visual perception threshold

Table 4 Data of Weibull distribution curves

Weibull distribution curve :
$Y=1-\exp\{-(x-r)^{m/b}\}$

where
Y : Perception ratio [%]
x : Maximum angular velocity [mrad/s]

Frequency [Hz]	m	b	m / b	r
0.152	3.05404	0.654353	4.6672668	0
0.202	1.4021	0.517991	2.7068038	0
0.303	1.90035	0.743321	2.5565671	0
0.606	2.2244	0.350098	6.3536495	0

Comparison of visual and physical perception

Figure 12 compares the results of the experiments of torsional visual perception and torsional physical perception. The figure indicates that visual perception is more sensitive than physical perception except in the case of translational motion. Therefore, the visual factor should be taken into account when proposing a new guideline for torsional motion.

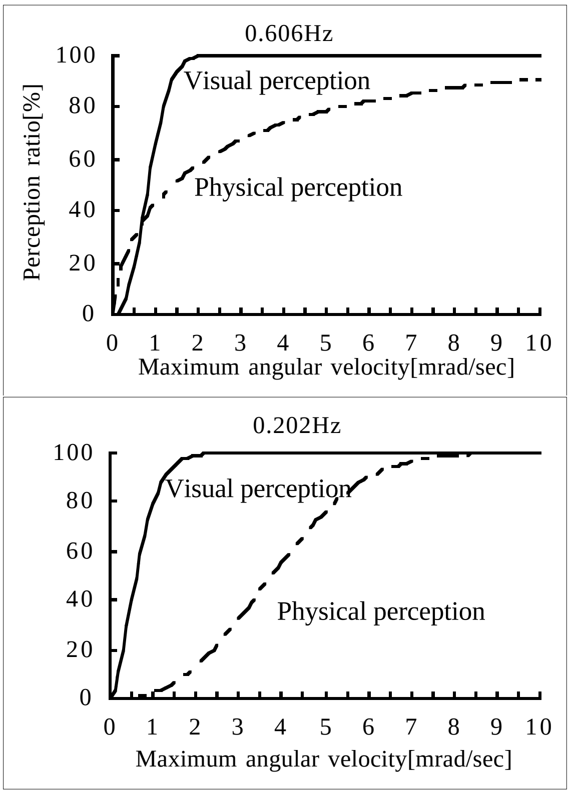


Figure 12 compares visual and physical perception.

CONCLUDING REMARKS

The authors have come to the following conclusions in this research:

(1) Measuring the degree of motion with a scale in angular velocity, the human visual perception threshold appears to be independent of the frequency of the torsional motion.

(2) Visual perception is more sensitive than physical perception except in the case of translational motion.

(3) Proposing a new guideline for torsional motion should include a consideration of the visual factor.

(4) Above results were gotten, and these coincide with existing literatures. Consequently, this editing method can be adaptable to these kind of simulations.

ACKNOWLEGEMANT

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