Shape-COG Illusion: Psychophysical Influence on Center-Of-Gravity Perception by Mixed-Reality Visual Stimulation

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Abstract

Mixed reality (MR) is a technology that merges real and virtual worlds in real time. In MR environments, visual appearance of a real object can be changed by superimposing a virtual object on it. In this study, we focus on the center-of-gravity (COG) and verify the influence of MR visual stimulation on the COG in MR environments. This paper describes the systematic experiments performed to study the influence. The results obtained are interesting: (1) the presence of COG can be changed by MR visual stimulation; (2) although COG differs in vision and force, the presence of COG can be represented by MR visual stimulation under certain conditions; (3) COG perception can also be changed by varying the mass of the real object. We named this psychophysical influence the "Shape-COG Illusion."

Keywords: Mixed Reality, Center-of-Gravity, Illusion, Psychophysical Influence, Visual Stimulation

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—

1 Introduction

Using mixed reality (MR) technology, real and virtual worlds can be merged [1]. In MR environments, the visual information of the virtual object can be superimposed on a real object with no change in tactual sense. In other words, users have the tactile feeling of the real object while viewing the superimposed digital data [2]. This implies that material and/or shape of the object can differ between visual and tactual sense. In such a situation, what kind of psychophysical phenomenon could be occurring? The user might feel uncomfortable. However, if the tactile sense is affected by the visual sense, it could be a kind of illusion. This paper describes the influence of visual stimulation on center-of-gravity sense in MR environments (**Fig. 1**). We conducted experiments to analyze the influence of visual stimulation on COG perception in MR environments.

2 Related Work

COG perception has been studied in terms of "dynamic touch," which is haptic perception with motion. For example, a person can recognize the length of a stick without looking at it by swinging the stick [3]. In the field of virtual reality (VR), methods to create an illusion of changing length or mass by a haptic stimulation have been studied [4]. However, the influence of visual stimulation on COG perception has not been investigated. In addition, "Size-Weight Illusion" is a well-known and typical illusion of weight [5]. When grasping objects of the same weight but different sizes, a person perceives the bigger object to be lighter than the smaller one. Moreover, Roch *et al.* confirmed that when a cube in a subject's hand appears larger through a magnifying glass, he/she perceives it as being lighter than actual [6]. In these studies show that perception of mass can be influenced by visual stimulation. Therefore we conduct some experiments about relationship of COG perception and visual stimulation in MR environments.

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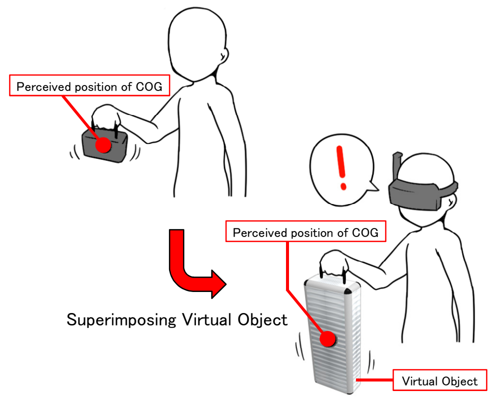
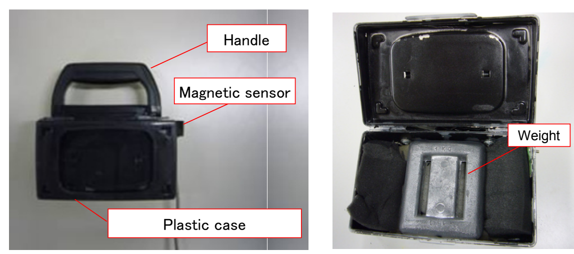


Fig. 1 The influence of visual stimulation on center-of-gravity sense in MR environments



(a) Appearance (b) Content

Fig. 2 Real object

3 Preparation of Experiment

In this study, we conducted three experiments to examine the influence of MR visual stimulation on COG perception. In Experiment, subjects pointed to the perceived COG position directly by using an input device. Using this device, the absolute COG position can be obtained without requiring a psychological measure.

As the real object used in the experiments, we employed a plastic case with the handle of a real attaché case (**Fig. 2(a)**). The dimensions of the plastic case were 155 mm (width) × 90 mm (height) × 65 mm (depth). The weight of the plastic case and the handle was 200 g in total. To adjust the mass of the real objects, weights of 150 g or 1,000 g were sealed inside the plastic case (Fig. 2(b)). As virtual objects used in the experiments, we employed CG models such as the attaché case shown in **Fig. 3** and **Tables 1**, which are available in many sizes and shapes. To

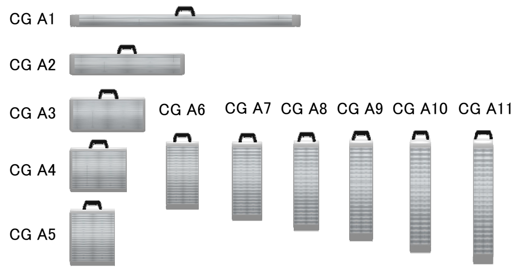


Fig. 3 Appearance of virtual objects used in the experiment

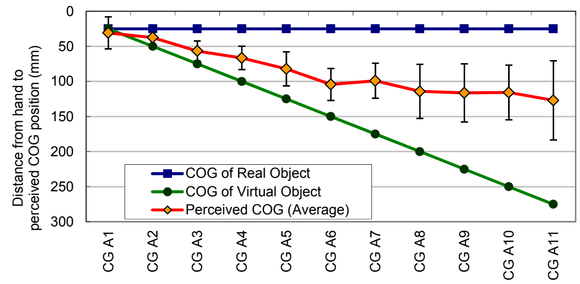
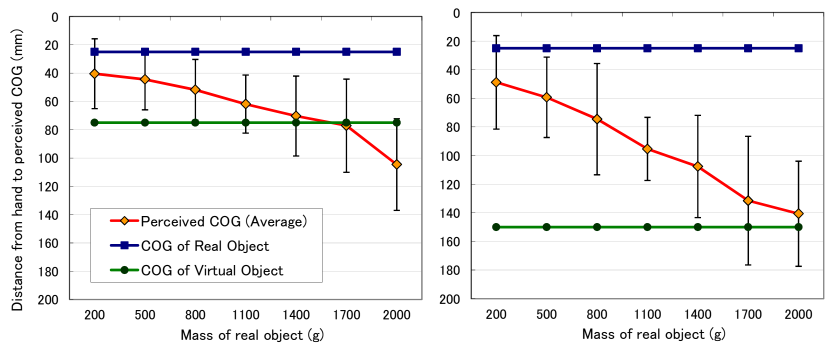


Fig. 4 Result of Experiment 1

Table 1 Size of virtual objects used in the experiments

	width × height (mm)
CG A1	1000.00 × 50.0000
CG A2	500.000 × 100.000
CG A3	333.333 × 150.000
CG A4	250.000 × 200.000
CG A5	200.000 × 250.000
CG A6	166.667 × 300.000
CG A7	142.857 × 350.000
CG A8	125.000 × 400.000
CG A9	111.111 × 450.000
CG A10	100.000 × 500.000
CG A11	90.9091 × 550.000

The depth of all virtual objects are 150 (mm)



(a) Superimposing CG A3 (b) Superimposing CG A6

Fig. 5 Result of Experiment 2

exclude the effect of size-weight illusion, virtual objects with the same volume but COG positions being changed by the aspect ratio of their shape are employed in the experiments.

4 Experiment 1

4.1 Procedure

Virtual objects with different aspect ratios (CG A1 to A11) were randomly superimposed onto the same real object. Fifteen subjects answered position of perceived COG.

4.2 Results

Fig. 4 shows the results of Experiment 1. Vertical axis shows the distance from the hand to the perceived COG position. Horizontal axis shows the mass of the real object. The results can be summarized as follows:

(i) The COG of real object is perceived in a different place than actual COG position by superimposing virtual objects
(ii) The perceived COG lies midway between the COG of the real object and the virtual object.
(iii) The effect of the COG illusion reduces by moving the virtual COG far away from the real COG.

5 Experiment 2

5.1 Procedure

Same virtual object (CG A3 or A6) was superimposed onto real objects with different mass (200, 500, 800, 1100, 1400, 1700, and 2000 grams). As a result, 14 combinations of objects were presented to the subjects. Fifteen subjects answered position of perceived COG.

5.2 Results

Fig. 5 shows the results of Experiment 2. The results can be summarized as follows:

(i) As the real object became heavier, the COG position was perceived to be farther from the subject's hand.
(ii) In all cases, the COG position of CG A3 was perceived to be farther from the hand than that of CG A6. Therefore the illusion of center-of-gravity appears to occur regardless of the difference in mass.
(iii) As the real object became heavier, the variation in the perceived COG position increased.

6 Conclusion

In this paper, we conducted experiments to examine the influence of superimposing virtual objects having different COG positions onto real objects. As a result, we confirmed that COG perception can be influenced by superimposing virtual objects, and we named this illusion the "Shape-COG Illusion." For the future, we will continue to study the occurrence of illusion of COG perception in other situations.

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