Improving Reliability of Virtual Collision Responses: A Cue Integration Technique

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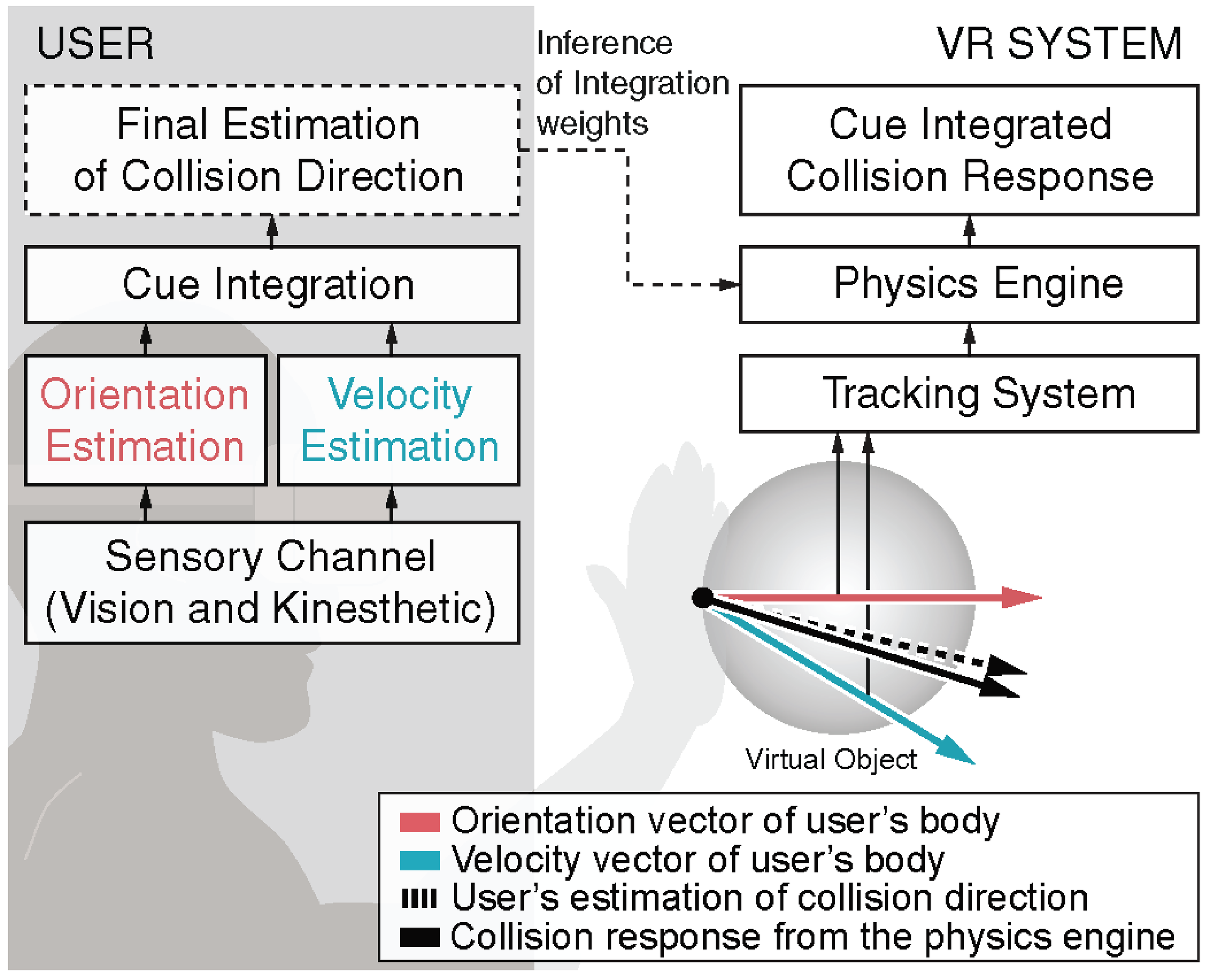
OVERVIEW

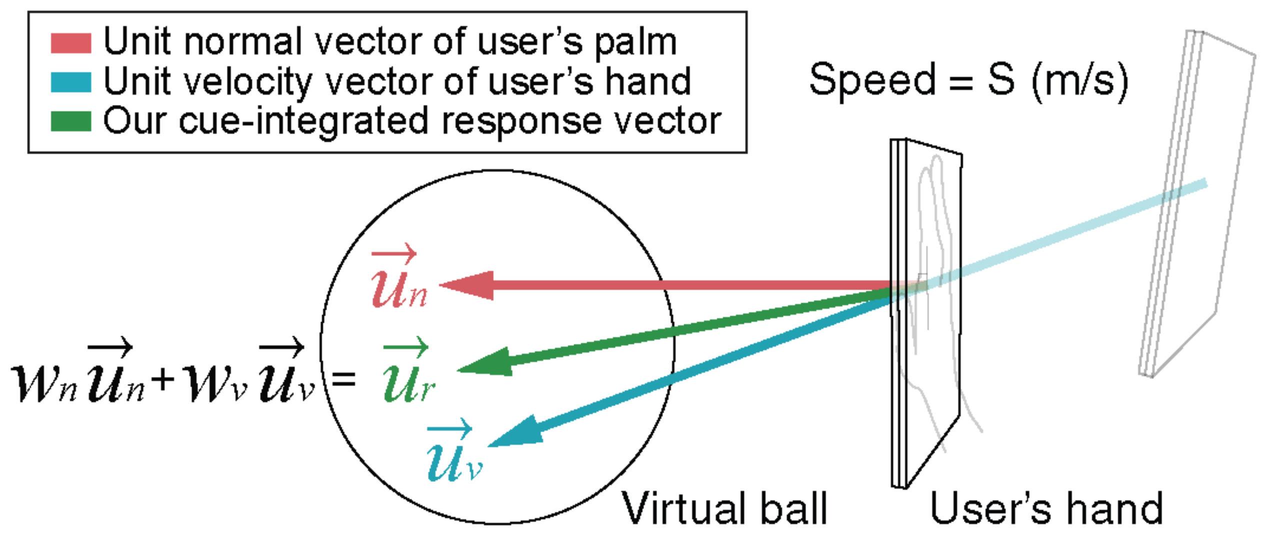
In virtual reality (VR), a user's virtual avatar can interact with a virtual object by colliding with it. If collision responses do not occur in the direction that the user expects, the user experiences severe degradation of accuracy and precision in applications such as VR sports games. In determining the response of a virtual collision, existing physics engines have not considered in which direction the user perceived and estimated the collision. Based on the cue *integration theory*, this study presents a statistical model explaining how users estimate the direction of a virtual collision from their body orientation vector and velocity vector. The accuracy and precision of virtual collisions can be improved by 8.77 % and 30.29 %, respectively, by setting the actual collision response in the direction that users perceive.



This study proposes a new collision technique that can improve the accuracy and precision of the collision response when a user's avatar and virtual object collide in VR. Based on the cue integration theory, the technique ensures that the direction of the collision response is the same as the direction of the collision that the user perceives.

THE CUE INTEGRATED VIRTUAL COLLISION RESPONSES

This study deals with a virtual collision between a virtual ball and a user's hand represented by a plate in the virtual space.



$$\vec{u}_r = w_n\vec{u}_n + w_v\vec{u}_v$$

$$\text{where } w_n = \frac{1/\sigma_n^2}{1/\sigma_n^2 + 1/\sigma_v^2} \text{ and } w_v = \frac{1/\sigma_v^2}{1/\sigma_n^2 + 1/\sigma_v^2}$$

$$\sigma_n = a_n \cdot \exp(b_n \cdot s) \text{ and } \sigma_v = a_v + 1/(\exp(b_v \cdot s) - 1)$$

a, b : The model parameters s : The hand speed

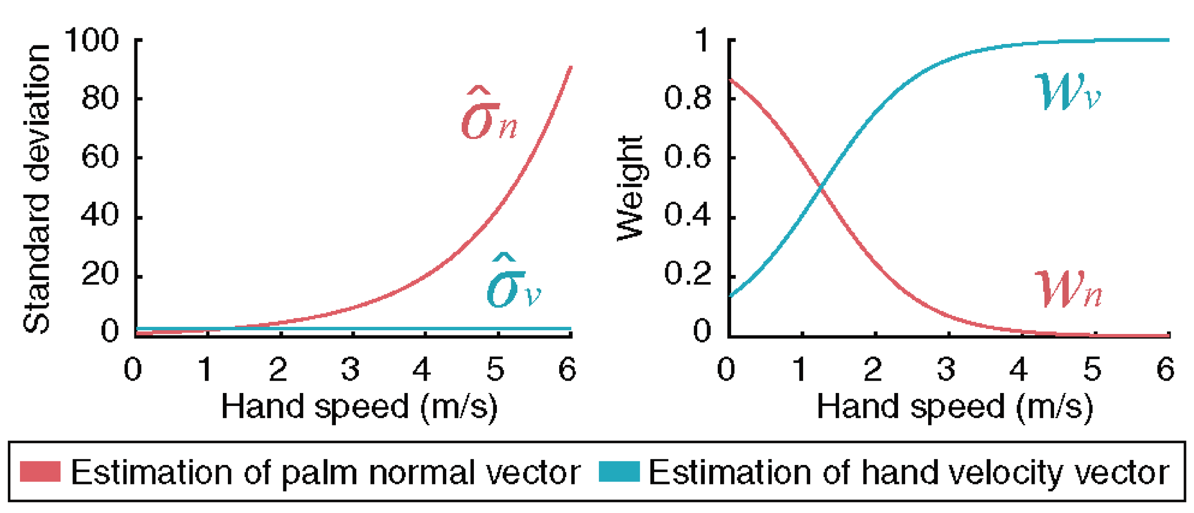
STUDY 1: CALIBRATION OF THE MODEL PARAMETERS

Method

- 16 participants were recruited (9 females, 7 males).
- Participants were required to collide their main hand in various proposed directions and speeds towards a virtual ball.
- 6×3×2 within-subject experiment with 3 independent variables: Ball Direction, Ball Speed, and Ball Diameter

Results

- The variance of the normal vector of the palm was directly proportional to the hand speed, while the variance of the velocity vector was inversely proportional to the hand speed.



a_n = 1.02
b_n = 0.75
a_v = 2.59
b_v = 173.32

STUDY 2: EVALUATION OF COLLISION TECHNIQUE

Method

- 18 participants were recruited (13 males, 5 females).
- Participants strike a virtual ball by hand.
- 2x2x2x2 within-subject experiment with 4 independent variables: Collision Technique, Target Speed, Friction, and Bounciness

Results

- Our cue integration collision technique has been shown to have significantly better accuracy (8.77 %), precision (30.29 %) and subjective performance score (26.8 %) than the conventional baseline.