Optical Marionette: Graphical Manipulation of Human’s Walking Direction

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Background | Redirected Walking

- Manipulation technique of human’s walking direction for VR environment
- Uses only visual feedback for the manipulation
- Enables users to explore a virtual world that is quite larger than the real environment

Figure by Matsumoto et al. 2016
Introduction | Motivation

- Suspected there are possibilities that human’s walking direction could be manipulated using only visual feedback in the real environment like a Redirected Walking in VR

Our goal

To manipulate user’s walking direction using only visual feedback in the real environment
Examined various image-processing methods to manipulate walking path

Investigated how to manipulate the walking path using the image-processing methods

We found effective reorienting method using an HMD in the real environment
Implementation

- The camera is attached to the HMD
- Users perceive the real world by video provided by an HMD and stereo camera
- So we can coordinate users’ sight in this setup
- HMD: Oculus Rift DK 2
- Stereo camera: Ovrvision
User’s sight via HMD + camera while walking
Implementation | Flow

Camera → Image processing to guide to imaginary direction → HMD
Image processing to guide to imaginary direction

Investigated effective image processing in a pilot study
Pilot Study

■ Purpose
  – To determine which of the image processing methods have the most effect on a human’s walking path

■ Participants
  – 5 participants (1 female); 18-22 ages

■ 6 image processing methods

■ Task
  – Walk straight 10 m for each image processing methods
Pilot Study | Result

Moving stripe pattern

Rotating image

Delayed image (only one side)

Magnification (only one side)

Distorted image (only one side, trapezoid)

Changing focal region

Delayed 0.5 sec
Implementation | Changing Focal Region (CFR)

Crops the raw image
Shifts the cropped area

Raw video from camera

Video that users see via HMD
Implementation | Changing Focal Region (CFR)

Crops the raw image
Shifts the cropped area

Raw video from camera

Video that users see via HMD

User is asked to go to the B, however, actually he is going to the A.
Experiment

- **Purpose**
  - To determine how to control the walking direction using Changing focal region method

- **Participants**
  - 16 participants
  - Had not prior knowledge of our experiment

- **Task**
  - Walk straight 24 m for each image processing
**Experiment | Experimental Design**

- **Image processing methods**
  - No processing (raw video)
  - Magnification
    - Magnification was added to the image-processing methods for comparison because it is used in Changing focal region method.
      This enabled us to identify the effects of image magnification and to reveal the pure effects of changing the focal region (shifting images).
  - **Changing focal region** (slow / fast)
    - Scroll speed of the cropped area in the slow condition was 0.5 px/frame
    - In the fast condition, the scroll speed of the cropped area was twice the scroll speed in the slow condition
**Experiment | Experimental Design**

**Locations**

- **Hallway**
  - Narrow
  - Several hints for spatial perception (such as walls)

- **Outside**
  - Large space
  - No hint for spatial perception
1. Completed pre-SSQ (Simulator Sickness Questionnaire)

2. Walked straight for 24 m each of image processing at 2 locations
   - At 4 m, guided to the left
   - At 14 m, guided to the right

3. Completed post-SSQ
Analyzed the SSQ scores with t-test

- No significant difference between pre-SSQ and post-SSQ
- Pre-SSQ: 4.7 (SD = 4.7)
- Post-SSQ: 6.7 (SD = 8.3)

I did not feel any motion sickness 😊
Result | No processing

10x Playback speed

![Graph showing position of participants vs distance from starting point]
Result | Changing focal region (fast)

▶ 10x Playback speed

Position of participants [m]

Distance from starting point [m]
Result

No processing

Changing focal region

No processing

Changing focal region
Result | Hallway

- **Significant effect**
  - No processing — Changing focal region (slow/fast)
  - Magnification — Changing focal region (slow/fast)

- **No significant effect**
  - No processing — Magnification
Result | Hallway

- **Amount of the manipulation for Changing focal region**
  - Slow: 65.3 mm/m
    - If you walk 2 m, your position moves by 10 cm horizontally
  - Fast: 75.3 mm/m

![Graph showing manipulation for different conditions](graph.png)

- *guide to left
- **guide to right

Legend:
- Normal
- Slow
- Fast

- No processing
- Magnification
- Changing focal region

Left:
- 72.4

Right:
- 99.2
Result | Outside

- **Significant effect**
  - No processing — Changing focal region (slow/fast)
  - Magnification — Changing focal region (slow/fast)

- **No significant effect**
  - No processing — Magnification
- **Amount of the manipulation for Changing focal region**

  - Slow: 105.2 mm/m
  - Fast: 199.2 mm/m
No significant effect between No processing and Magnification

- This indicates that the cropped image by itself did not affect the participants’ walking paths.
- It is clear that the participants’ walking paths were affected by movement of the cropped area of Changing focal region.
Result | Hallway vs. Outside

- Significant effect within the locations
  - The outside participants were affected more by the manipulation method
    - In the hallway, the participants could not move more than 1.1 m because the width of the hallway is 2.2 m
    - Thus, the mean value of the position change in the hallway was smaller than that in the outside
Changing focal region (fast) was significantly more effective than the slow condition

- Slow: 105.2 mm/m
- Fast: 199.2 mm/m (at outside)
Past research reported Changing the FOV has effects on spatial perception [1, 2]

In this study

- No horizontal spatial perception effect on our result because no significant difference between No processing and Magnification

- By contrast, we could not determine whether there was any depth perception effect


Conventional navigations require users to recognize information (go to the right) and then follow directions.

Our method directly affects users’ bodies so that it can control them without requiring user recognition process.

Does our method have lighter burden than conventional navigations?
Significant amount of cognitive resources is required for redirected walking in VR [3]

Similarly, our method might require some cognitive resources

We plan to investigate how much cognitive resources are really required by users to follow the manipulation

Discussion | Feasibility

- Demonstrated our method at SIGGRAPH 2016 E-Tech
- Over 700 people were successfully manipulated
In see-through AR contents, to control of human’s walking path is important because users might conflict each other.
There is possibility of walker navigation system, if we can increase the amount of manipulation of users’ walking direction.
Related Work | Galvanic vestibular stimulation (GVS) [4]

- Administers electrical stimulation to the back of ears (the vestibules)
- Controls the walker’s sense of balance

EMS-based walker navigation system

Controls walker’s legs using EMS

Related Work

- These methods use electrical stimulation

- Our method is **vision-based** manipulation technique of human’s walking direction using *only* visual feedback

We found effective image-processing methods for walker movement control with an HMD

We investigated the effects of the image-processing methods via a user study

Changing focal region method was most effective, and changed walking path by about 200 mm/m

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