A Vision-Based Fiducial Object Input Device for Intuitive Interaction

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Abstract

- **Human-computer interaction** is crucial for daily activities, requiring **intuitive**, **adaptable**, and **precise** mechanisms.
- Presentation of a **novel vision-based input device** using **computer vision** and **fiducial object pose estimation f**or seamless digital interaction.
- The proposal provides an **accessible** and **engaging alternative** to conventional input methods, **reducing barriers** for people with diverse needs.
- To prove its performance, **an interactive experience was designed**, allowing users to manipulate 3D objects through the developed input device.
- A preliminary user study showed **high satisfaction**, highlighting **fluidity**, **intuitiveness**, and **ease of use**. The study shows vision-based input have a **great potentia**l for improving interaction paradigms in **educational** and **general-purpose computing environments**.

Keywords

Tangible interaction, User interface, Fiducial object, Fiducial marker, Input device.

Introduction and Related Works

Motivation
- Traditional inputs lack 3D interaction
- Vision systems sensitive to occlusion
- Need for accessible systems

Development of a customized

3D Input device

Based on

Fiducial objects
- Trackable from any angle
- Low processing cost
- Real-time performance

Having as background

Related works
- Design of customized Fiducial Objects [1]
- Customized markers detection [2]
- Promising applications: Dodecapen [3]

User guided by an assistant

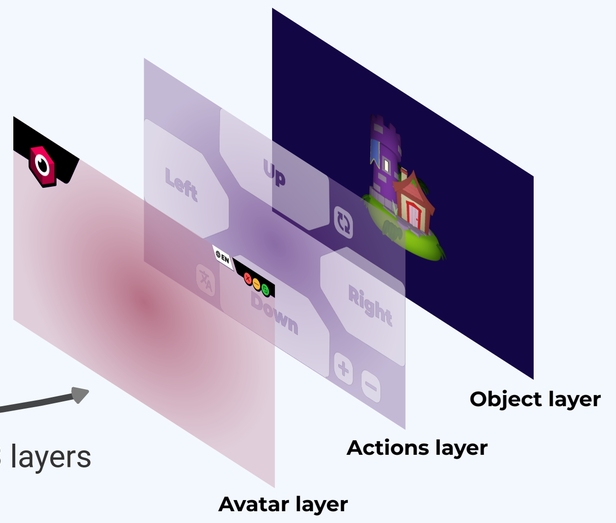
Markie

Design and Methodology

Required Setup

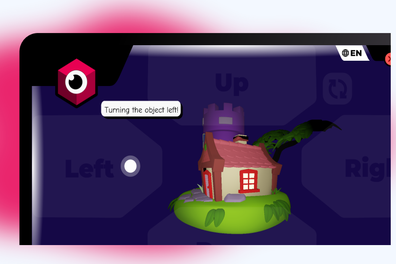
Interface design

Composed by 3 layers



Method

1st Detection — **2nd Action selection** — **3rd User feedback**



Results

Evaluation Summary
- 21 participants (experts and non-experts)
- Setup composed by:
  - Uncalibrated laptop camera
  - Dodecaedrum as Fiducial Object
- Assessed on 5 dimensions using Likert-scale
- All average scores > 4.0 / 5

Key Results
- Functional vision-based input device
- Interactive experience with inclusive interaction guided by Markie
- Participants adapted quickly without prior instructions
- Participants' feedback:
  - Initial uncertainty but low learning curve
  - Huge potential for gaming and interactive learning
  - User friendly interface and fluid interaction

Conclusions & Future work

Main contributions

1. **Human-computer interaction** demands **intuitive, adaptable,** and **precise** mechanisms for seamless engagement.
2. We present a **vision-based input device** leveraging **fiducial object pose estimation** to translate **user actions** into **system commands.**
3. The system enables users to **manipulate objects in 3D scenes**, offering an **accessible alternative** that **reduces barriers** for students with **diverse needs**.
4. A **structured user study** confirmed the device's **high usability, responsiveness**, **fluidity**, and **ease of use**, validating its potential for **educationa**l and **general-purpose** environments.

As future work:

1. Conduct a **more extensive evaluation** with a **larger, more demographically diverse** user base to validate the system's **generalizability**.
2. Design a **predefined action flow** to guide users more clearly through the interaction process and **reduce early-stage uncertainty**.
3. Explore **applications** beyond **education**, such as **gaming**, **simulation**, and **assistive technologies** to broaden the system's impact.

[1] Pablo García-Ruíz, Francisco J. Romero-Ramírez, Rafael Muñoz-Salinas, Manuel J. Marín-Jiménez, and Rafael Medina-Carnicer. **Fiducial objects: Custom design and evaluation.** *Sensors*, 23(24), 2023.

[2] David Jurado-Rodriguez, Rafael Muñoz-Salinas, Sergio Garrido-Jurado, Rafael Medina-Carnicer. **Design, detection, and tracking of customized fiducial markers**. *IEEE ACCESS* 9, 140066–140078, 2021.

[3] Wu, P.C., Wang, R., Kin, K., Twigg, C., Han, S., Yang, M.H., Chien, S.Y.: **Dodecapen: Accurate 6dof tracking of a passive stylus**. pp. 365–374. 30th Annual ACM Symposium on User Interface Software and Technology (2017).

Artificial Vision Applications