

A visually realistic grasping system for object manipulation and interaction in virtual reality environments

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A visually realistic, flexible and robust grasping system for real-time interaction in Virtual Reality environments



- VR objects extracted from the YCB dataset [Çalli 2017].
- Hands are controlled using handheld devices (e.g. Oculus Touch).
- Implemented in Unreal Engine 4.
- Qualitative analysis:
 - motor control.
 - finger movement realism.
 - interaction realism.
- Quantitative analysis:
 - novel metric quantifying hand-object overlapping.
 - time needed to grasp each object.

- Lack of realism of existing interactions in VR applications using handheld controllers.
 - Distance-based grasping.
 - Predefined grasp animations.
- Lack of open-source approaches.
- Extract data from visually realistic interactions with everyday objects.

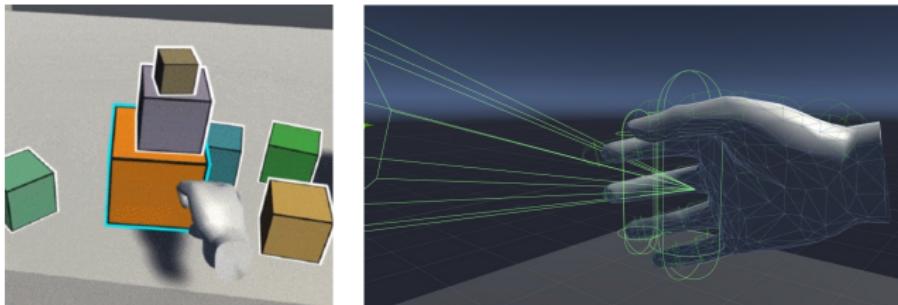


Figure: Distance grab example from Oculus Sample Framework [ocu]

The essence of our grasping system is how the hand is automatically fitted to the object shape. Our methodology consists of two main stages:

- Virtual hand configuration:
 - Choose the grasp animation according to a grasp taxonomy proposed by Feix et al. [Feix 2016].
 - Experimentally place the capsule triggers on the phalanges.
- Grasping pipeline design and implementation.

Choose the grasp animation

- We analyzed 33 different grasp types from the taxonomy.
- The cylindrical grasp:
 - Power grasp.
 - Palm opposition.

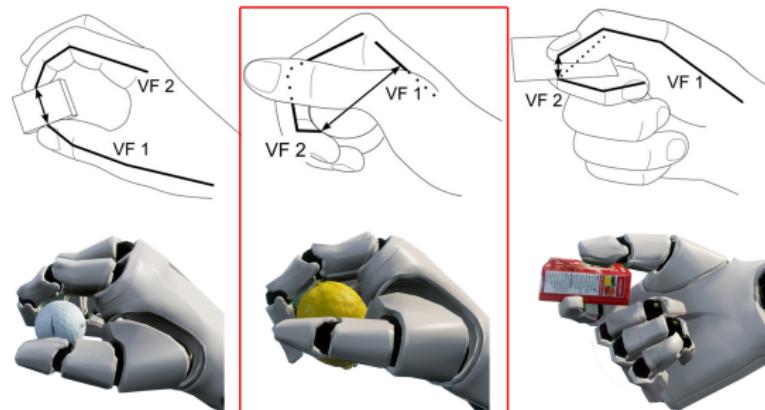


Figure: From left to right: pad, palm and side opposition.

Triggers placement

- Progressively increase the number of capsules maintaining performance.
- Interact with small and different shaped objects using capsules only on the distal phalanges.
 - Slippery behavior because of the collision with middle phalanges.
 - **Solution:** put capsule triggers on the middle phalanges.
- Put a sphere trigger on the hand palm to enable palm opposition.

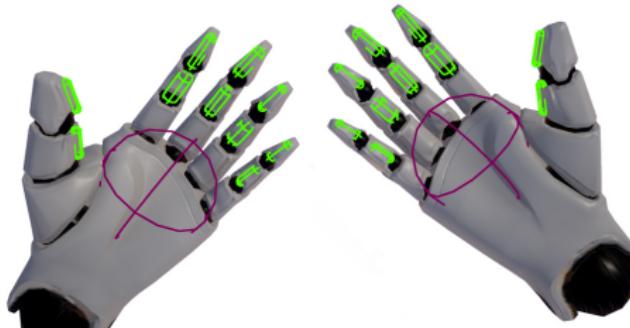
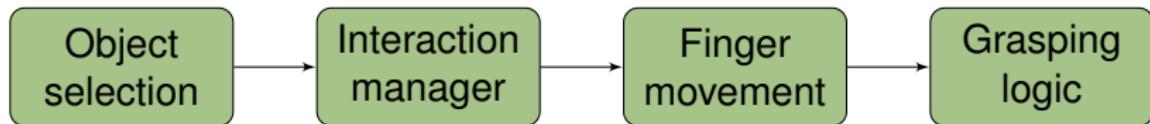


Figure: In green, capsule triggers of the middle and distal phalanges. In purple, sphere triggers used to detect the nearest object the the hand palm.



- Object selection:
 - selects the nearest object to the hand palm.
- Interaction manager:
 - manages the capsule triggers placed on finger phalanges.
 - determines phalanx state (blocked/released).
- Finger movement:
 - controls individual finger movement during interaction.
- Grasping logic:
 - decides when to grab or release an object.

A qualitative evaluation:

- based on: user experience interaction in a photorealistic environment.
- to assess: interaction realism, immersion, hand movement naturalness, etc.

A novel quantitative evaluation:

- novel error metric.
- time needed to grasp the objects.

Performance analysis- dataset



(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)



(i)



(j)



(k)



(l)



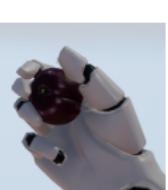
(m)



(n)



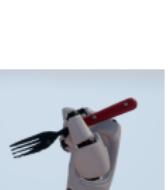
(o)



(p)



(q)



(r)



(s)



(t)



(u)

Performance analysis- dataset

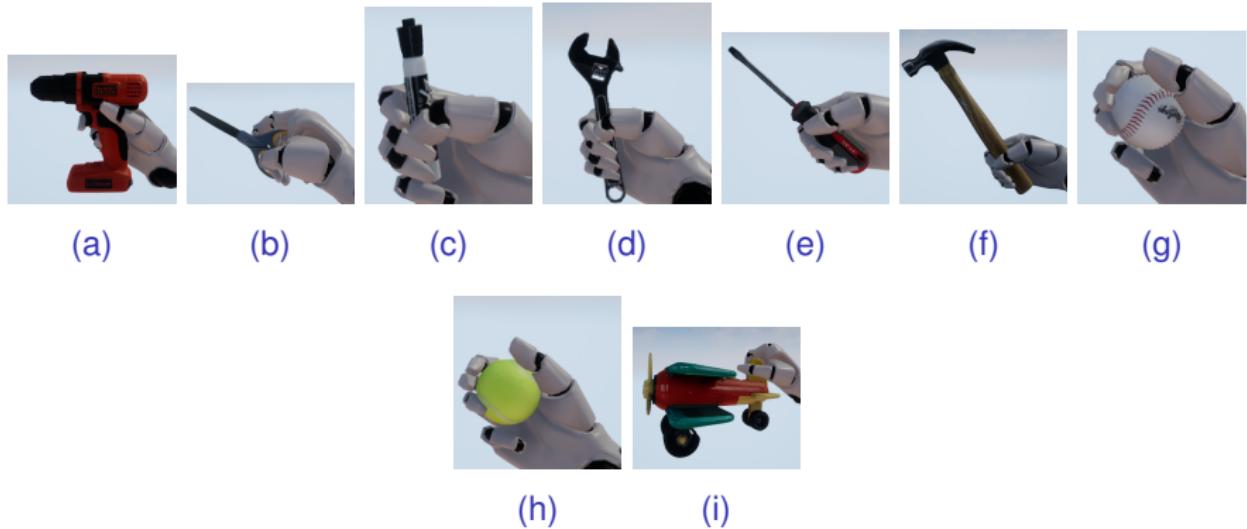


Figure: Grasping performed on objects from the YCB dataset.

ID	Question
<i>Aspect 1: Motor Control</i>	
Q1	I felt like I could control the virtual hands as if it were my own hands
Q2	The movements of the virtual hands were caused by my movements
Q3	I felt as if the movements of the virtual hands were influencing my own movements
Q4	I felt as if the virtual hands were moving by themselves
<i>Aspect 2: Finger Movement Realism</i>	
Q5	It seemed that finger movements were smooth and plausible
Q6	I felt fingers open and close in a natural way
Q7	Fingers react adequately to my intentions
<i>Aspect 3: Interaction Realism</i>	
Q8	I felt like I could grab objects wherever I wanted to
Q9	It seemed as if the virtual fingers were mine when grabbing an object
Q10	I felt that grabbing objects was clumsy and hard to achieve
Q11	It seemed as if finger movement were guided and unnatural
Q12	I felt that grasps were visually correct and natural
Q13	I felt that grasps were physically correct and natural
Q14	It seemed that fingers were adapting properly to the different geometries

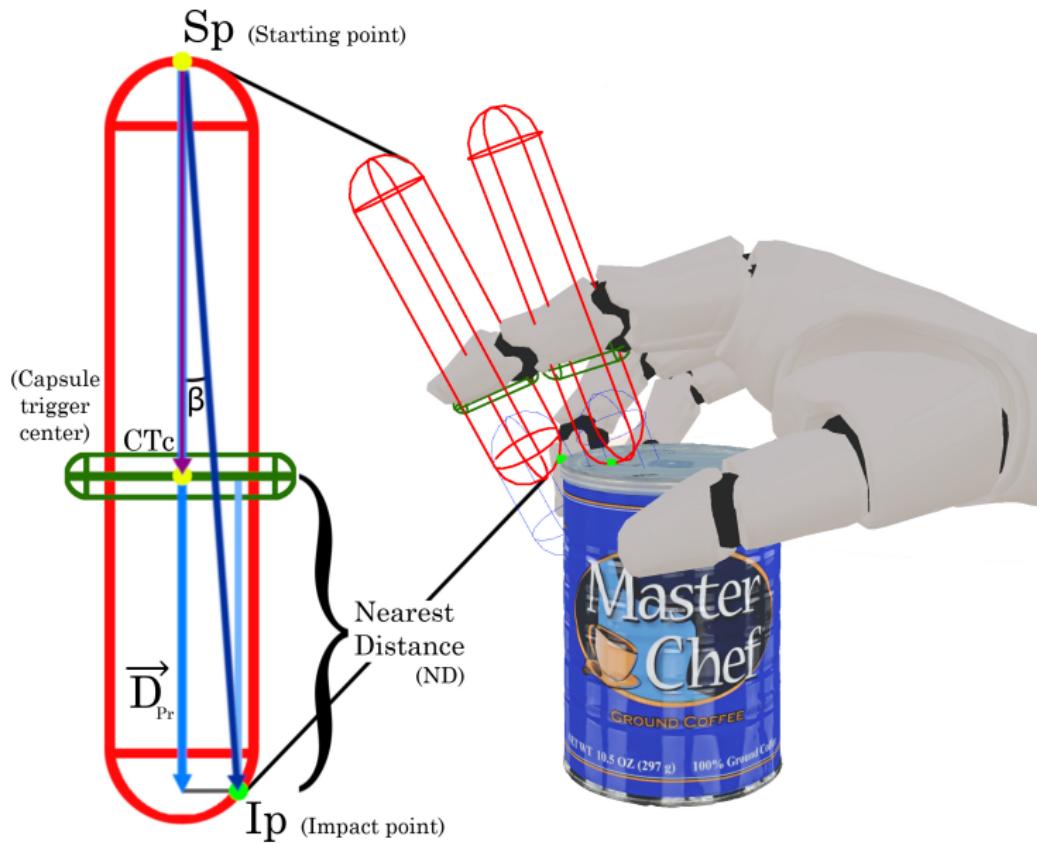
Table: User evaluation questionnaire.

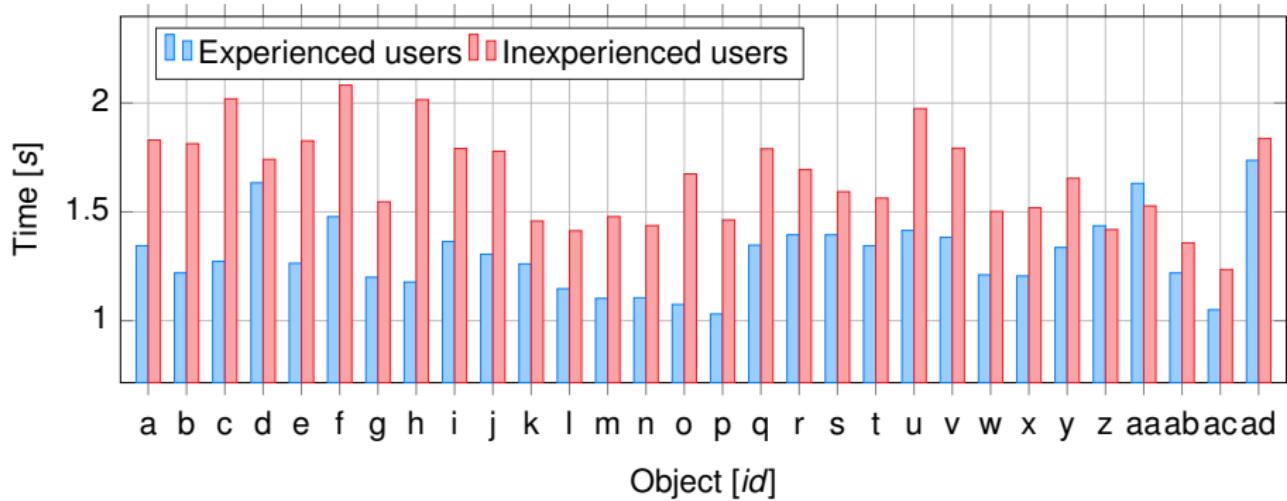
Evaluation Aspects	Score	
	Experienced users	Inexperienced users
(1) Motor Control	1.85	2.34
(2) Finger Movement Realism	2.33	2.51
(3) Interaction Realism	1.84	1.95
Embodiment score	1.97	2.19

Table: Score for each qualitative aspect of the evaluation and group of participants.

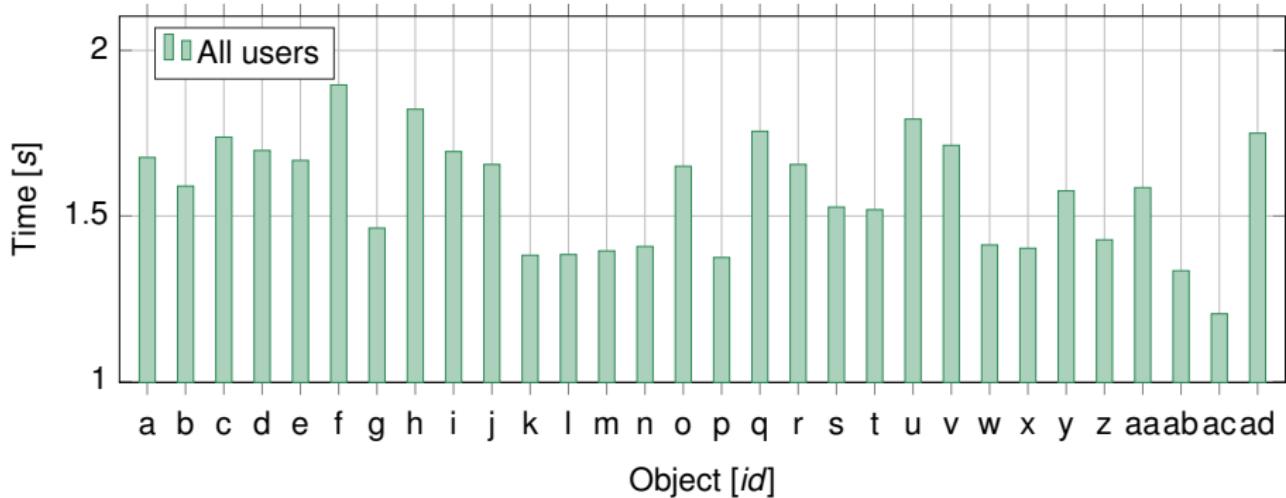
- 7-point Likert-scale [-3,3].
- Average result of 2.08.

Performance analysis- quantitative

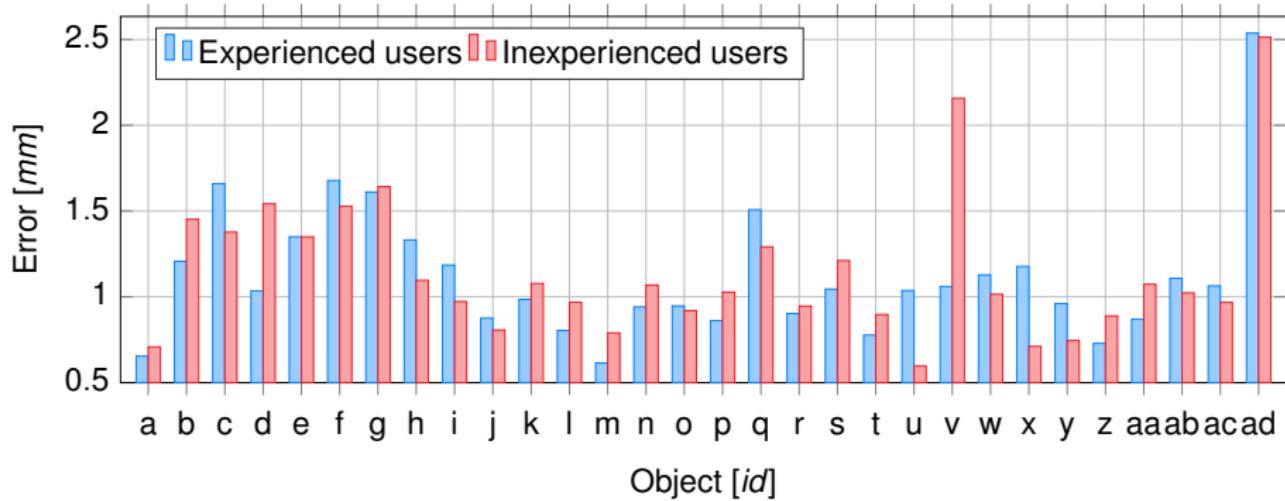




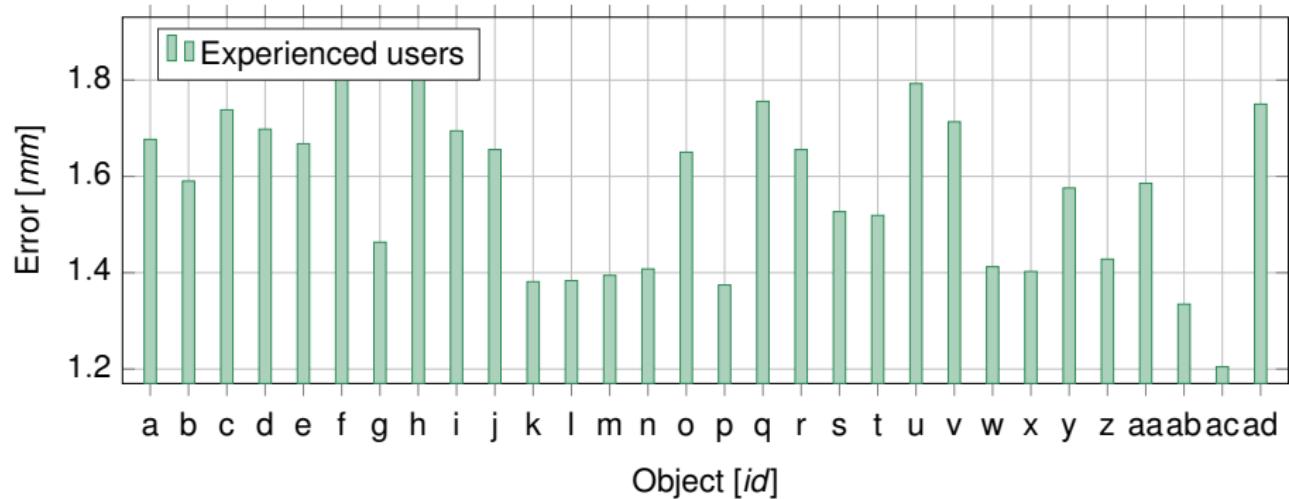
- Inexperienced users have taken longer to grasp the objects.
- More time is needed because of random spawn.



- Larger objects are more time consuming.
- Less time is needed as the user gains experience.



- Similar results regardless of previous VR experience.
- Most differences: power drill (u) and spatula (v).



- Large objects are the most error-prone.
- Overall error is decreasing progressively.

- Robotics: human-robot knowledge transfer.
- Rehabilitation: patients with hand motor difficulties.
- Data generation.

- Single animation for hand closing.
- Cannot grasp one object with both hands at the same time.
- Interaction with large objects require VR skills.

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-  Berk Çalli, Arjun Singh, James Bruce, Aaron Walsman, Kurt Konolige, Siddhartha S. Srinivasa, Pieter Abbeel et Aaron M. Dollar.
Yale-CMU-Berkeley dataset for robotic manipulation research.
I. J. Robotics Res., vol. 36, pages 261–268, 2017.
-  Thomas Feix, Javier Romero, Heinz-Bodo Schmiedmayer,
Aaron M Dollar et Danica Kragic.
The grasp taxonomy of human grasp types.
IEEE Transactions on Human-Machine Systems, vol. 46, no. 1,
pages 66–77, 2016.
-  *Distance Grab Sample Now Available in Oculus Unity Sample Framework*, Septembre.

Grasping logic

$$f(th_{ph}, in_{ph}, mi_{ph}, palm) = \begin{cases} \text{true,} & \text{if } (th_{ph} \vee palm) \\ & \wedge (in_{ph} \vee mi_{ph}) \\ \text{false,} & \text{otherwise} \end{cases} \quad (1)$$

, where th_{ph} , in_{ph} , and mi_{ph} are defined as

$$\begin{aligned} th_{ph} &= thumb_{mid} \vee thumb_{dist} \\ in_{ph} &= index_{mid} \vee index_{dist} \\ mi_{ph} &= middle_{mid} \vee middle_{dist} \end{aligned} \quad (2)$$

$$\text{Motor Control} = ((Q1 + Q2) - (Q3 + Q4))/4$$

$$\text{Finger Movement Realism} = (Q5 + Q6 + Q7)/3$$

$$\begin{aligned}\text{Interaction Realism} = & ((Q8 + Q9) - (Q10 + Q11)) \\ & + (Q12 + Q13 + Q14)/7\end{aligned}\tag{3}$$

, using the results of each individual aspect, we obtain the total embodiment score as follows:

$$\begin{aligned}\text{Score} = & (\text{Motor Control} + \text{Finger Movement Realism} \\ & + \text{Interaction Realism} * 2)/4\end{aligned}\tag{4}$$