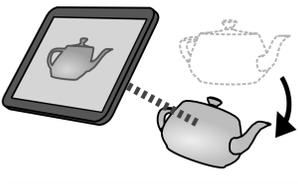
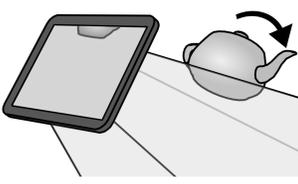


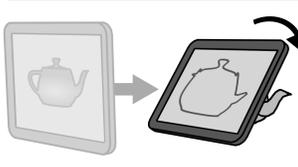
## Introduction

Using a mobile device as a “tangible handle” for 3D manipulation has many advantages: it provides full 6-DOF control, in a completely portable and self-contained device.

However, this approach also comes with a number of problems. These problems are caused by the necessary **separation** between the mobile device and the manipulated object:

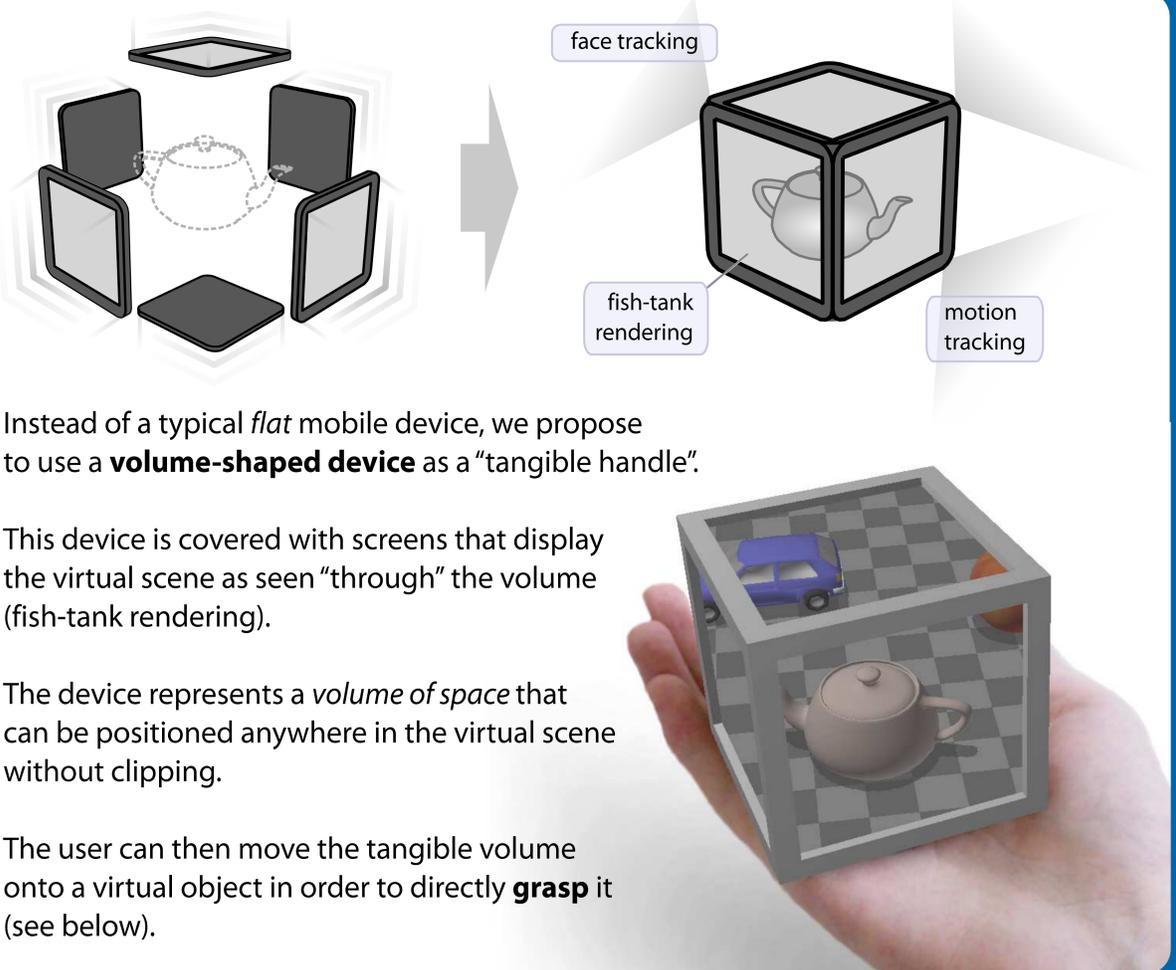
- 

**Attaching the object to the device** [1]  
✗ rotations are made difficult by the separation
- 

**Manipulating the object in-place** [2]  
✗ the object can leave the field of view
- 

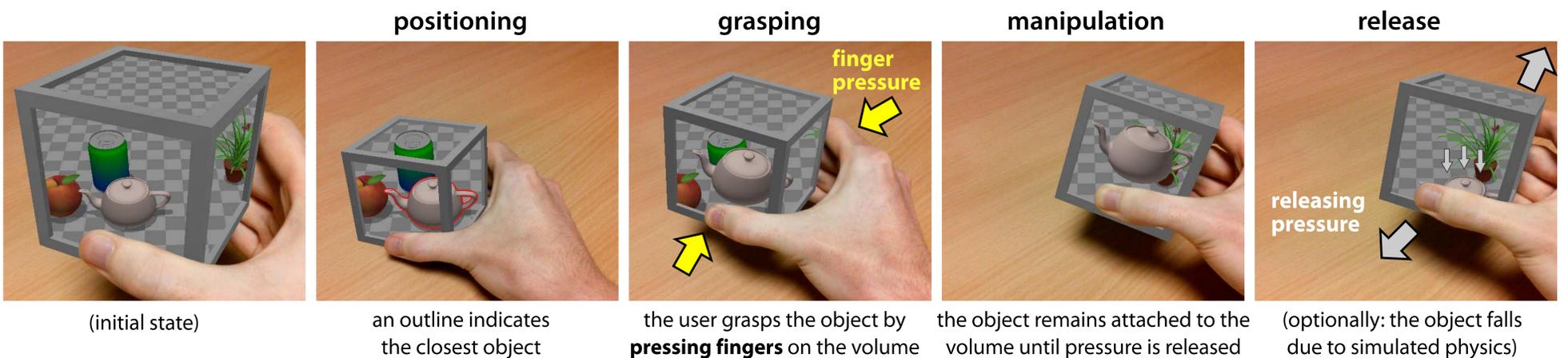
**Moving the device onto the virtual object**  
✗ eliminates the separation, but results in clipping

## Our concept: a portable interaction volume



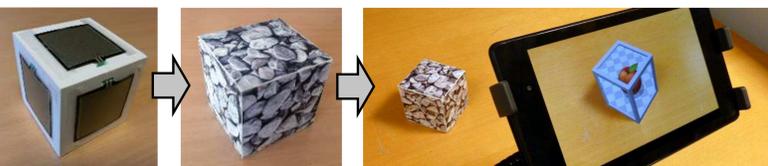
## Manipulating virtual objects

In our concept, the user can position the tangible volume around a virtual object. In order to pick it up and manipulate it, we designed a **grasping** technique directly inspired from real-world manipulation: **pressing and holding fingers** on the volume. This is implemented by adding **pressure sensors** under the display surface of the device.



## Preliminary prototype

We created a partial prototype of this concept to be able to conduct user studies. Currently, the screens that should cover the device are simulated in augmented reality. Although this is sufficient for evaluating the concept, we intend to build a more complete and truly self-contained device in the future.



## References

- [1] A. Henrysson, M. Billinghurst, and M. Ollila, “Virtual object manipulation using a mobile phone,” ICAT ’05 (2005).
- [2] A. Mossel, B. Venditti, and H. Kaufmann, “3DTouch and HOMER-S: intuitive manipulation techniques for one-handed handheld augmented reality,” VRIC ’13 (2013).

## Evaluation

To evaluate the **intuitiveness** of this new form of 3D interaction, we asked 36 participants to perform an object manipulation task **with no prior instructions** about how to use the tangible volume.

**Three successive hints** could be requested by participants to help them complete the task. We measured the number of hints used during the experiment:

| Hints requested                                  | Total success rate |
|--|--------------------|
| <b>no help requested</b>                         | <b>53%</b>         |
| “put the device onto the object”                 | 55%                |
| “press the device to grab the object”            | 100%               |
| “move the device while maintaining the pressure” | N/A                |

Among the 19 participants who did not need any help, the average completion time was **63.5** seconds.

Therefore, more than half of the participants discovered **by themselves** and within a reasonable time how to grasp and manipulate virtual objects with this new device.