# Hand-Based Interaction on a Millimeter Scale in Virtual and Augmented Reality

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**Abstract:** Interaction with mixed-reality systems is often performed using input devices or simple gestures. Another promising concept for interacting with mixed-reality systems is hands-free interaction on a millimeter scale where a precise tracking of small finger movements is utilized for interaction. However, because of technological difficulties, this field has not been researched sufficiently yet. In this poster, we present properties and challenges of hand-based interaction on a millimeter scale.

**Keywords:** Hand Tracking, Single Hand Micro Gestures, Tracking Quality, Interaction

## 1 Introduction

Our hands are the primary means of interaction with our physical surroundings, both through the dexterous grasp and manipulation of objects. In addition, we developed specialized tools that are designed for the usage with our hands. As a result of centuries of complex, fine-grained hand-based interactions, the motor functions of the hands are the most complex and advanced of all human motor skills.

However, for interacting with the digital world, the human hand is still limited to a small number of some very specific inputs. Interacting with a computer mouse means moving it in a 2D plane and using, in most cases, only two fingers for interaction. Interacting with mobile devices is limited to usually one to three fingers on a movable 2D plane and sometimes some additional gestures like shaking of the device. In virtual environments, the most common form of interaction is using a generalized input device, that consists of several buttons or other control elements and can be moved in 3D. A free-hands interaction with digital content is still difficult to achieve and, in most cases, limited to some simple gestures that can easily be detected by a computer's sensory system. In our research, we are especially interested in designing hand-based interaction in a subtle way on a millimeter-scale, for example single-hand micro gestures, where even the smallest movements can be utilized as user input.

Exploiting the full potential of the human hand's range of motions on such a small scale for interacting with digital content is still difficult from a technical point of view and has not been examined thoroughly from the scientific perspective. But it contains a high potential and technological advancements in recent years in the area of image-based machine learning approaches to tracking the human hand promise the feasibility in some years. Thinking

Veröffentlicht durch die Gesellschaft für Informatik e.V. 2020 in B. Weyers, C. Lürig, D. Zielasko (Hrsg.):
GI VR / AR Workshop 2020, 24. - 25, September 2020, Trier.

http://dx.doi.org/10.18420/vrar2020_22

ahead, a free-hands interaction in combination with a retina display as access to a mixed-reality world where digital content and real world merge is a very intriguing idea that might become reality and seems worth exploring. A logical step towards this vision is a hands-free interaction in virtual environments without controllers or restricting instrumentation. This idea is, however, still limited by technology, as the performance of commercially available hand tracking systems fails in many cases at certain aspects which limits the open-minded prototyping in research.
In the following, we give a quick introduction to requirements of hand-based interaction on a millimeter scale and present challenging aspects of designing those systems.

## 2 Hand-based Interaction in Virtual Reality

Providing precise hand tracking is a challenging task as it is technologically very demanding. We distinguish different quality levels for finger tracking systems. On lower levels, systems utilize clearly defined interactions that are mapped directly to inputs. With a higher level, both, the complexity of tracking and possible interactions increase and more universal approaches to interaction become possible. These levels can be seen as a continuum from low-fidelity to high-fidelity with higher levels extending features of previous levels.

1. **Events**: Only specific actions such as static or dynamic gestures are recognized. They can be defined as complex movement, for example the *bloom*-gesture of Microsoft's *Hololens* or simple movement such as stretching out one finger. They are not registered in 3D space and are utilized in a binary way, for example as clicking technique.
2. **3D Input**: For 3D-input, the hand's position in tracking space is combined with simple events. For example, a tap and hold of thumb and index (a pinch gesture) can be used to indicate a drag and drop action to move virtual objects in 3D-space as manipulation task.
3. **Partial Tracking**: The hand is held in a certain interaction pose (for example slightly pronated in front of a head mounted display, or above an interaction device) and only parts of the hand are tracked with high accuracy. For example, thumb, index and middle finger are tracked as continuous movements that control basic controls [LGK+16, SMH+18] or precise positions on the hand are utilized as specific inputs [HCY+16]. Some commercially available systems such as Leap Motion, Oculus Quest's experimental finger tracking or some simple data gloves provide partial tracking as it is sufficient for many applications.
4. **Full Tracking**: A full tracking of a single hand in 3D-space. All joint angles are tracked accurately and can be utilized for interaction. The hand model approximates a user's hand to provide a millimeter-scale accuracy of finger tips and other universally specifiable points for interaction. Many systems seem to aim at this level but are limited due to external factors or complexity of tracking.

5. **Universal Tracking**: Support for special features such as multi-hand and multi-user, on-body [HEB+17] and on-object [SRS19] interaction that allow novel mixed-reality systems. Current commercially available system often fail at these tasks.

## 3 Challenges of Precise Finger Tracking

In research and development some typical challenges have to be tackled to make designing hand-based interactions on a millimeter-scale possible. Commercial system often fail to provide certain features and can therefore not be used in experimental development. In the following, we present the most weighty factors that limit the design of interaction prototypes which we experience in our work. **Accuracy and precision** are key factors for stable and reliable interaction. Current approaches only yield a tracking error of around 10mm to 30mm [YGHS+18, SOK+20] which is too large for the intended concept of interaction. A high individual variation in bone sizes, range of motion and physical interaction can be observed [LN05], which makes the use of a **precise model** of the user's hand necessary. To obtain such a model, a calibration procedure can be performed or the hand model is fitted to the user's hand while interacting with the system. Unfortunately, in many systems, it is unclear how closely the real hand shape is actually approximated by the virtual model. For tracking, in some cases the fingers need to be equipped with hardware (for example gloves or electronics), which limits **comfort** and might cause restrictions in movement which in turn can impact the perception and applicability of a tracking system. Depending on the approach, various **technological flaws** can be experienced, for example computation time, drift, noise, delay, non-linearity or self-occlusion. Additionally **external factors** such as (infrared) light for optical systems or magnetic fields for electronics-based systems can heavily impact tracking. Further, there is no standardized quality rating for hand tracking systems, which impede the comparison of systems. Many factors such as individual hand shape, setup (e.g. lighting and background), arrangement of hand and tracking system, the use of dynamic or static gestures and the specific task impact the performance, which makes the definition of a universal metric difficult. If a system is intended to be used outside of interaction research in a laboratory, finger tracking becomes even more challenging, as it should be mobile, affordable, universal and ready-to-use with ideally no maintenance and calibration.

## 4 Conclusion and Future Work

Hand-based interacting on a millimeter-scale seems promising for interaction in the field of mixed reality and might be an alternative to hand-held input devices in many cases. From our own experience, the flaws of currently available systems do often not allow a free design of such systems, which limits the research activity in this field. The recent advancements in current technology, especially in the field of artificial intelligence and neural networks, suggest that sufficient systems might be available in the near future which allow further exploration of this form of interaction.

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