Bauhaus-Universität Weimar
Faculty of Media
Degree Program Computer Science and Media

Can't Touch This - A Prototype for Public Pointing Interaction

Master Thesis

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Date of Submission: 2nd December 2014

Abstract

Museums can be perceived as old fashioned. Potential audiences therefore often do not consider visiting one for themselves. Nevertheless, there are many modern and open minded ones, which are willing to experiment with new possibilities, to get rid of their dusted reputation and to evolve.
In order to increase interactive potential of exhibits behind glass, I implemented a novel information interaction system for a museum of pre- and protohistoric history. The challenge was not only to develop a working, intuitive prototype, but also consider low maintenance and robustness for everyday use. The system I developed employs the natural behavior of visitors by detecting potential users and enabling them to interact with the system via pointing gestures. Additionally, the museum personnel can easily set up and maintain the system themselves.
Interaction of the system is initiated automatically with a visitor walking up to the installation. No additional devices on the users side are required, they only need to point at one of the interactive exhibits inside the showcase. The system then determines which exhibit is addressed and displays corresponding information in the form of explanatory texts and detailed images on a screen.

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Abbrevations

IMI Interactive Museum Installation

MS Microsoft

RFID Radio-Frequency Identification

FSD Functional Specification Document

MIT Massachusetts Institute of Technology

SDMS Spacial Data-Management System

WYSIWYG ”What you see is what you get”

GUI Graphical User Interface

SUI Single-User Interface

MUI Multi-User Interface

HCI Human Computer-Interaction

TUI Tangible User Interface

VR Virtual Reality

3D three-dimensional

HMD head-mounted display

DOF degrees of freedom

AR Augmented Reality

SDK Software Development Kit

CAVE Cave Automatic Virtual Environment

2D	two-dimensional
BCI	Brain-Computer Interface
MVT	Museumsverband Thüringen
HDD	Hard Disk Drive
PDLC	Polymer Dispersed Liquid Crystal
IR	infra-red
FUBI	Full Body Interaction
UI	User Interface
wpm	words per minute
cpm	characters per minute
IV	Independent Variable
SD	Standard Deviation
ID	Identificator
AOA	Area of Affinity
LOS	Length of Stay
n/s	not specified
SUS	Standard Usability Scale

1 Background and Motivation

Over time, public places became more and more enriched with all kinds of technology. Nowadays, on nearly every corner something is beeping or blinking and buttons, leavers and knobs make us - their potential users - interact with our environment. This trend does not spare anyone or anything. Even traditionally calm and sophisticated places open up to the possibilities of contemporary technologies.

1.1 Museums

Museums, much like libraries, are foremost seen as a place of knowledge and its preservation. Hence, visitors behave in a very reserved manner. Whilst applying for libraries, museums are willing to involve people instead of merely providing information. Many museums therefore employ guides, who give tours and tell visitors about the exhibits. In addition to their factual knowledge, they also provide interesting anecdotes and other exciting information needed to bond with a certain topic. Apart of instructive and teaching staff, museums have tried many other ways to involve their visitors. One of those is utilizing technology. With time technology evolved, and so did technological augmentations in museums.
The name ”museum” comes from the ancient greek's ”Museion”. It refers to a sanctified place in honor of a muse [20]. Basically, museums are collections of arts and science or at least parts of them on display. In modern history, those collections were of an artistic nature and mostly private. Later, scientific and otherwise cultural museums were established for the general public [ibid.].
One of the first high-tech installation of the modern age was the *Diorama*. In 1821,

Louis Jacque Mandé Daguerre[1] and the painter Charles Marie Bouton partnered up to develop this spectacle. It is an elaborate combination of painting and lighting [27]. Through ingenious lighting, the paintings became vivid. This way, a diorama could simulate the moods of a whole day within minutes. Thus, it is seen as an early predecessor of the cinema. Even today, although in much smaller size, dioramas are still of certain interest [22].
The first interactive displays appeared at the *Urania* in Berlin around 1889, when they introduces visitor-activated models and a scientific theater. In 1907 the *Deutsches Museum* in Munich also began experimenting with film and mechanical models, which were operated by visitors [19]. Later, other museums all over the world followed. Since then the

> *"[...] wider museological community's understanding of nature and purpose of interactiveness"* [26]

has taken shape.

> *"This understanding almost invariably involves:*
>
> 1. *The presence of some technological medium.*
> 2. *A physical exhibit which is added to the main display.*
> 3. *A device which the visitor can operate, involving physical activity."* [26]

As electronics and microchips evolved, computers became popular and affordable. The technological equipment of museums grew with what was available and new kinds of devices and installations appeared. Today, nearly every museum has a certain guide system such as an audio guide. It either leads visitors through the museum on a predefined course or a visitor can choose the track according to a given code for each included exhibit. In 2004, Chou et al. compared different museum guide systems in various categories, which were considered necessary to provide a user-friendly and informative experience. Expositors, tape machines, CD-players and a PDA were judged. The PDA was most versatile and easy to use system [8] (see Figure 1.1). The described system had the portability of an audio guide, but due to position recognition the PDA would always

1 Daguerre is a scene painter and stage designer by trade. He also is the inventor of the first photographic process called daguerreotypy

present the current exhibit. The system could replace common audio guides and immobile information terminals all together. In addition, it still was able to give predefined tours depending on the user's interests.

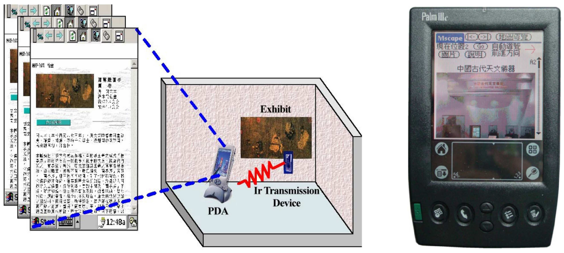

Figure 1.1: A conceptual sketch of the guide system (left) and the GUI of its application on a PDA [8].

Yet another chapter was opened, when the internet and wireless communication were introduced. Museums began to also maintain websites. Burgard et al. went a step further, included robotics and build an autonomous tour-guide robot called *RHINO* [7] depicted in Figure 1.2. It was able to navigate through the museum freely and without bumping into visitors. On demand, RHINO worked as an information terminal for present visitors and it could be used as a tour-guide as well, because it had a simple build-in web interface. Thus, the museum's contents where simultaneously used by the website and the robotic tour-guide. RHINO was deployed at the *Deutsches Museum Bonn* in 1998 [ibid.].

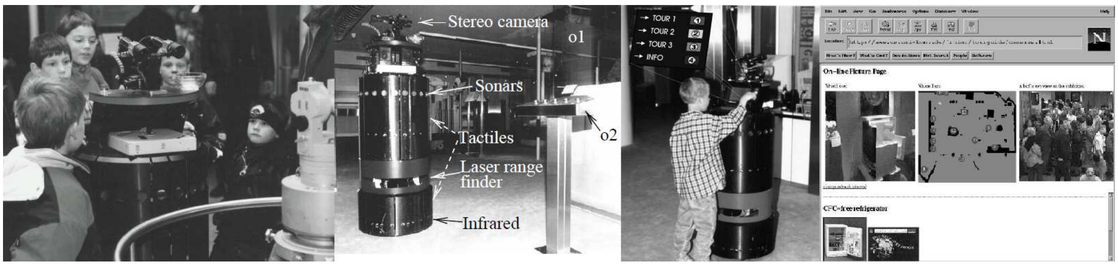

Figure 1.2: An overview of the RHINO tour guide robot [7].

In 2002, a group from the *University of Limmerick* made a survey in *Hunt Museum*. The museum is owned and run by the Hunt-family. Its tradition is to involve the visitors since its early days. Therefor, they had so-called *cabinets of curiosity* [9], special compartments within the exhibition, where additional exhibits were hidden. For example, a curious visitor had to open drawers in order to find a collection of plates (see Figure 1.3). Via this exploration, the visitors became involved. Inspired by their observations, Ciolfi et al. implemented a completely new and interactive part of the exhibition in 2003 [11]. Two new rooms were introduced. First, there was the *study room* with three interactive devices for getting further information about certain exhibits. They were disguised as a chest, a painting and the interactive desk depicted in Figure 1.3. The second room, the *room of opinion*, was plain white with plinths, on which visitors could record their interpretations of the intended function of certain exhibits. In order to manage all the data, a third and hidden room was used to host all the data-servers.

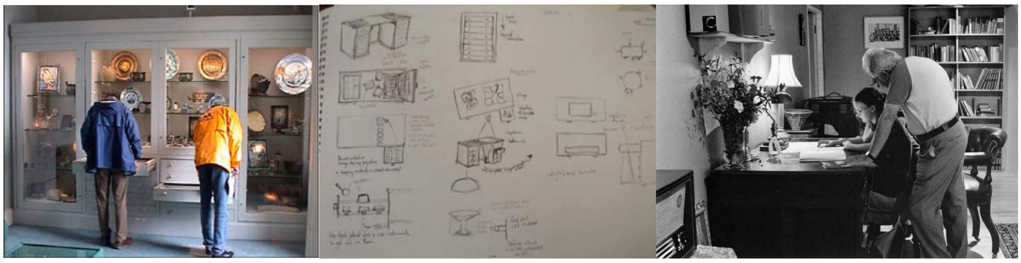

Figure 1.3: Cabinets of curiosity at the Hunt Museum (left) [9] and a conceptual drawing (middle) [ibid.] of the later interactive desk (right) [11].

The *medien.welten*-exhibition at *Technisches Museum Wien* was not only showcasing technical devices from all eras and genres of modern media, it also invited visitors to make use of some. As Hornecker et al. described in [16], throughout the exhibition users were given opportunities to produce their own medial content. The interfaces ranged from an abacus over a telegraph to a whole rebuild of a news-studio from an Austrian TV-channel. Figure 1.4 shows those and other installations.

Figure 1.4: The abacus, news-studio, and telegraph installation at the medien.welten [16].

Visitors of medien.welten could not only use the devices, but also store some of their produced contents in a *digital backpack* [ibid.]. This way, visitors did not only have an exciting experience, but also something to remember it by later.

1.2 Interfaces and Interaction

People visiting a museum come from different backgrounds and in various numbers. There can be large groups like a school class on a field trip or a single person strolling around. Their technical and physical abilities might also vary. Hence, an installation's ease of use, especially in a museological context, is of great importance. Because the interface is the only connection between users and the system, it has to be as intuitive and easy to use as possible. It dictates the way of interaction and, therefore, whether the whole systems works or not. A ground breaking system is worth nothing without proper interaction between its operator and it. This presents the need for suitable kinds of input and feedback. Thus, Ben Shneiderman once introduced his *eight golden rules of interface design*:

1. *"Strive for consistency.*
2. *Enable frequent users to use shortcuts.*
3. *Offer informative feedback.*
4. *Design dialogs to yield closure.*
5. *Offer error prevention and simple error handling.*

6. *Permit easy reversal of actions.*

7. *Support internal locus of control.*

8. *Reduce short-term memory load."* [23]

Following this guideline should yield a well operable interface. However, there still might be particular difficulties for specialized or novel systems. Especially public user-interfaces bring new factors, which are not explicitly included in Shneiderman's rules. How should an interface behave,

- in order to invite users?
- on a user's first encounter?
- if there are multiple users?

The ideal interface should be as intuitive and naturally to use as possible. This requirement was already addressed in 1980 by Richard A. Bolt. He described the *Media Room* at Massachusetts Institute of Technology (MIT) shown in Figure 1.5 as an office with a chair, a wall-sized screen and other analogue or electronic installations. The room's equipment allowed the user to navigate through the *Spacial Data-Management System (SDMS)* called *Dataland*. The user would sit down and had several input-devices at its disposal. One of them was a small device that could measure its position and orientation in space. The device was used to calculate where on the big screen the user was pointing. In combination with simple voice-commands the user was able to create and manipulate geometrical primitives [5].

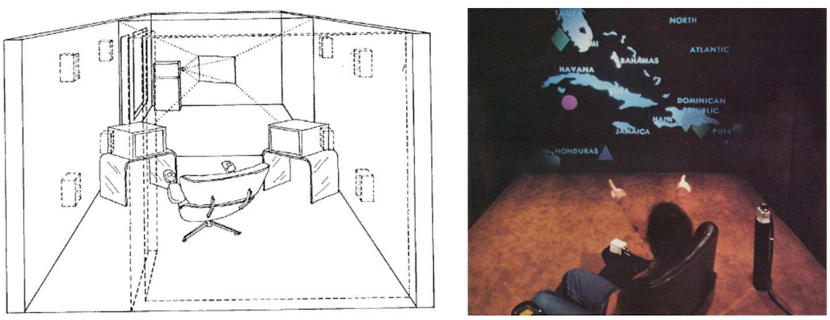

Figure 1.5: Sketch of the Media Room (left) and interaction inside it with free-hand pointing gestures and voice commands [5].

Since then, this seemingly futuristic furnishing could not be established as a common way of interaction. Keyboard and Mouse are still the most widely used input-devices. Meanwhile, touchscreens and voice-recognition are closing the gap though. The principle of "What you see is what you get" (WYSIWYG)[2] became of ever greater importance. Many interfaces are designed with Shneiderman's rules and usability in mind. Developments in Human Computer-Interaction (HCI) seem promising. More intuitive devices and interfaces are developed and tested thoroughly.

There are basically two types of interfaces. A Single-User Interface (SUI) is designed to be operated by only one user, whereas a Multi-User Interface (MUI) can be operated by a group of users at once. However, there is no strict distinction between the two. People might look over a SUI's user's shoulder and give instructions, or a lone person could operate a MUI on its own. Another factor that influences how people use an interface is the occasion. Public interfaces, such as a kiosk system at a cinema or for photo-developing provide a GUI on a touchscreen. Those systems are intended to be used by a single user, but might also be confronted with groups. Azad et al. investigated how groups behave around such kiosks. Most groups approached the interface asynchronously. Meaning, one member is interacting with the system, while the others watch. As time passes, the rest of the group might get more active due to *intra-group communication.* They further observed, that

> *"there is a semantic, profound difference between pointing and touching. Users who point are communicating ideas within a social group and may not want the technology to treat it as input."* [4]

Moreover, inter-group communication is also of great importance. Shyness or frustration may inhibit an individual or group from interacting with a system. Strangers can ease the use, when they act as an example or explain their actions to those shy or frustrated [15].

Interfaces can not only be categorized by their intended demographics. Input- and output-devices dictate the kind of interaction. As mentioned earlier, keyboard and mouse are being replaced with novel technologies. Touchscreens and voice recognition

2 WYSIWYG first came up in the 1970s, when the first office-programs appeared. Due to different resolution-densities of displays and printers, it was necessary to show correct relations of letters and page. Later on, the term was synonymously used for Graphical User Interface (GUI)-elements.

have become established means of input as well. Moreover, novel approaches towards interaction are made and influenced by novel possibilities in technology. Museums in particular strive for innovative interfaces to involve visitors and, therefore, tend to explore many fields of interactive possibilities.

> *"Interactive exhibitions are thriving, encouraged by a new approach to museology developed in response to current social demand and a much more participatory philosophy involving a redefinition of the concept of the museum in general and of the science museum in particular. [...] The classic concept of observation has been replaced by that of participation."* [10]

A Tangible User Interface (TUI) is a very natural approach. Here, a tangible object represents a digital entity. This could be a virtual object or something more abstract like an operation or property. Those tangibles can be used to interact with a system or even each other. In [25], Ullmer et al. described the principle of *token and contraint*, which played an influential role during the conception and is revisited in Chapter **??**. Two name-giving types of tangibles are involved, tokens and constraints. They have two phases of interaction. At first, tangibles can be associated, which means that their physical shape dictates, whether tokens will or will not work with a particular constraint. After that, the constraint's properties dictate the further way of interaction as shown in Figure 1.6. In comparison to ordinary interfaces a TUI offers more haptic perception. This could increase a user's attention to the interface and as a consequence their involvement with a possibly related exhibit.

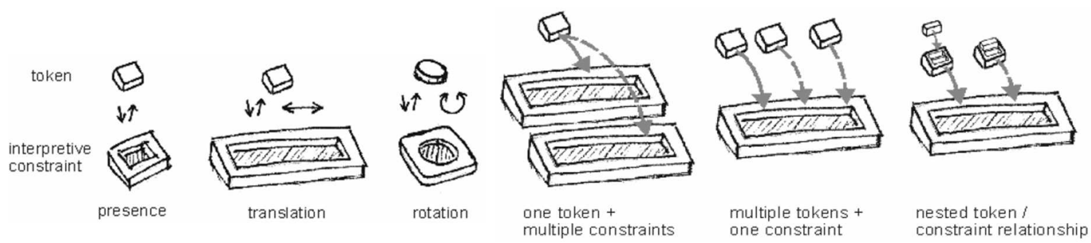

Figure 1.6: Basic and more complex combinations of token and constraints [25].

Apperceptive and playful interfaces might raise visitors' involvement. Groups of visitors tend to spend more time with an interactive exhibit, because the majority wants to make the experience for itself [10].

VR provides a less tangible approach. Contemporary VR-systems offer a way to display and manipulate three-dimensional (3D) data in real-time. Users can be immersed into vast, 3D environments, which are projected on huge stereoscopic displays or shown by a head-mounted display (HMD)[3]. Those systems require a special kind of interaction to either navigate through or select objects in the virtual environment. Therefore, special interaction metaphors were developed. Proper navigation can be realized via any input-device capable of six degrees of freedom (DOF)[4] and is rather familiar. But, since navigating to each object in order to select and manipulate it is inconvenient, a separate metaphor for interacting with objects had to be developed as well. Thus, a pointing device was introduced. In order to calculate its correct position and direction it has reflective markers in a unique pattern, which are then tracked by a system of infrared cameras (see Figure 1.7a) [3]. A virtual ray into the scene is calculated accordingly. Basically, objects can be selected by pointing at them and triggering selection in some way. *A survey of 3D object selection techniques for virtual environments* showed that 29 of 31 reviewed techniques were based on ray-interaction. The remaining two used a hand avatar like in Figure 1.7b. Both of them track a user's hand and one also applies ray-based leverage to extend reach [2].

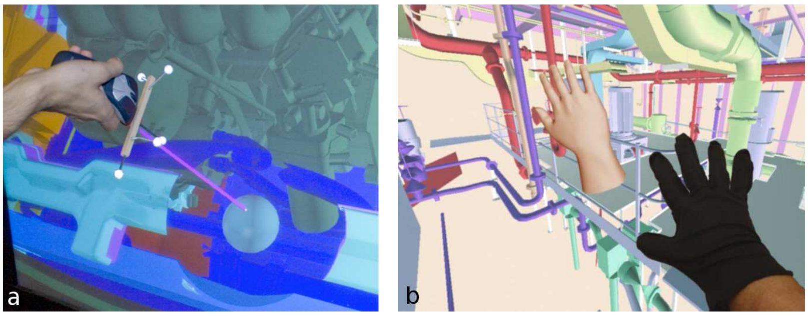

Figure 1.7: a) Pointing device with reflective markers [3]. b) Hand with tracked glove and the respective hand avatar in the VR-environment [2].

3 Recent examples are *Occulus Rift* and *Google Glasses*. While Occulus Rift provides a completely closed solution for VR-environments, the Google Glasses are an Augmented Reality (AR)-approach.

4 One DOF is either translation along or rotation around one spacial axis. Hence, there are six possible movements in 3D space.

As mentioned earlier, keyboard and mouse are established means of input, though there are more natural ways of input though. Humans have been communicating with gestures for ages. With this in mind, *gestural interaction* arose as a concept in HCI. In [18] five basic categories of gesture styles are defined. All those gestures can be applied to two- and three-dimensional interfaces. *Deictic* gestures are defining a location and include all varieties of pointing gestures [ibid.]. They range from the cursor on a desktop PC to the VR-pointing devices mentioned above. *Manipulative* gestures are used for translation, rotation, and scaling [ibid.]. Here, the "pinch to zoom"-gesture for many touch-based devices is probably the most commonly known. More abstract gestures are *semaphoric* and language gestures [ibid.]. They consist of designated signs or movements and can be static or dynamic. The best example for static gestures is sign language. Air traffic controllers use flag waving to guide planes into parking positions by semaphoric gestures. The last category is *gesticulation* [ibid.]. In contrast to semaphoric gestures, gesticulation is purely natural and does not have to be learned. Gestures often appear in combination with speech, why they are also called *coverbial* gestures.

Gestures are naturally motivated. Thus, gesture-based interfaces should be intuitive to interact with. Through the introduction of smart phones and tablet computers touch-based interaction and gesture-based interfaces are getting more and more relevant. In 2003, the *EyeToy for PlayStation2* began to show the possibilities of *free-hand gestures*. A few years later, Microsoft began selling the *Kinect for Xbox 360*. Independent drivers and software for it were developed almost immediately, which enabled developers and researchers to utilize the system's capabilities on regular computers. The official Software Development Kit (SDK) and *Kinect for Windows* followed about half a year later. Other devices like *ASUS Xtion PRO* followed working with the identical internal hardware. The more detailed hardware specifications will be explained in Chapter **??**. This development introduced a low cost solution for user-tracking, whilst the aforementioned tracking systems for VR are very expensive. Several interfaces were developed making use of the hardware's potential.
The *Data*^{3} is an interface based in a Kinect sensor to interact with a database [14]. It is an approach to visually handle multidimensional datasets. Therefore, the gestures of a user are interpreted and recognized by a middleware. This middleware then produces events upon which the Data^3-interface changes the view on the 3D dataset or certain properties about it. Although the input data provided by the depth sensor is three-

dimensional, the gestures that are interpretable are restricted to one or two axes [ibid.]. A similar approach is followed by *Kinoogle*, which is a *natural user interface* [6]. Here, several gestures were defined to navigate in *Google Earth* and *Street View*. The four gestures depicted in Figure 1.8 were defined to operate the GUI of Google Earth. Therefore, *panning*, *zooming*, *rotate*, and *tilt* gestures are mapped to mouse and keyboard inputs.

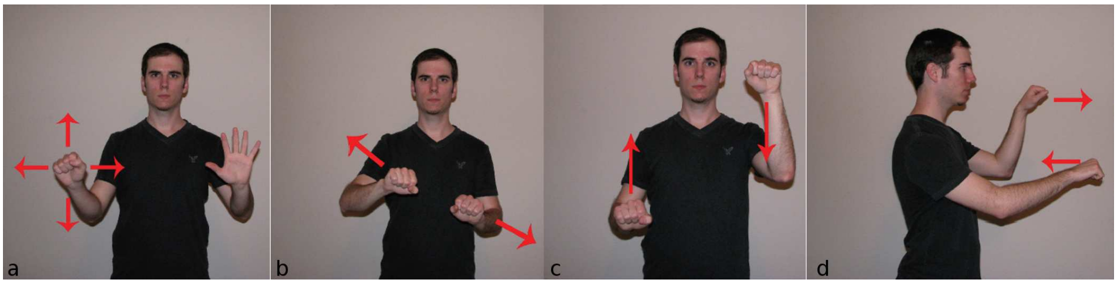

Figure 1.8: Gestures used for panning (a), zooming (b), rotating (c), and tilting (d) maps in Kinoogle [6].

For each gesture, all axes are monitored to recognize an event. However, an event is triggered by certain changes on one or two axes. For instance, the rotation gesture is based on the relation of both hands of the user to each other. Therefore, their x- and y-values are observed and evaluated [6]. The remaining gestures work in a similar fashion. In virtual 3D-environments low cost depth sensors are used as well. Thus, a Kinect can be utilized to track a user inside a Cave Automatic Virtual Environment (CAVE)[5] to calculate correct perspectives for him or her [17]. Figure 1.9 shows a user inside the CAVE once as a standard image and once as depth image.

5 A CAVE is a special VR-setup with multiple screens. This produces more immersion than an ordinary single screen-setup. To provide correct perspectives for a user, its head position and orientation have to be reliably tracked. Otherwise, there might be unpleasant artifacts or even errors between the different screens.

Figure 1.9: User inside the CAVE at HTW Berlin seen with in a normal image (left) and by the depth sensor with the joints of the skeleton tracking (right) [17].

Jung et al. are tracking the shoulders and head of a user. Those tracked points are then combined to form an orientation matrix upon which a *sufficiently correct perspective* can be displayed [17]. If the tracking data is flawed, the perspective is also compromised. Hence, such a system has to be robust and reliable.

As a consequence of these developments, the performance and suitability of low cost tracking solutions for VR-tasks was examined. Ren and O'Neill stated that

> *"More and more information and other content is visualized and manipulated in 3D, bringing a corresponding increase in the importance of effective and usable 2D user interfaces."* [21]

They conducted two kinds of test. First, they looked into two-dimensional (2D) interaction techniques such as touchscreens and *freehand 3D* interaction and described similarities and differences. Accordingly, both techniques' WYSIWYG-approach makes them spontaneous and direct. This natural *walk-up-and-use* interaction style decreases the interaction cost for any possible user. Further, users are able to move freely, because there are no extra devices to pick up and operate [21]. In the second test, the low cost solution was evaluated for common 3D interaction techniques in VR-environments. Thereupon, Ren et al. came up with a *design guideline for 3D freehand interaction* [ibid.].

- Avoid single actions with either high accuracy or keeping the hand up for long.
- Use goal crossing [1] as a trigger.
- Map complex 3D-movements on 2D interaction.

- Use the extra dimension as a trigger.
- Avoid uncomfortable hand or arm positions.

In the end, Ren and O'Neill concluded:

> *"Freehand gestural selection enabled by a single low cost camera is a potentially valuable technique enabling flexible, low configuration interaction in 3D environments, without any requirement for dedicated devices to be worn on or carried by the user. With appropriate designs, freehand 3D interaction can share the appealing fluidity and immediacy of currently popular multi-touch surfaces, [...] enabling walk-up-and-use access to services, holding the promise of wide applications for ordinary users in everyday life."* [21]

1.3 Goal of this Work

After having gathered experiences with several of the aforementioned interaction techniques, I intended to combine those experiences into a unique interface. Especially the intuitive motivation behind tangibles, touch-based interfaces and the immersive nature of VR-environments are interesting fields.

> *"Unfortunately, current user interfaces often lack adequate support for 3D interactions: 2D desktop systems are limited in cases where natural interaction with 3D content is required, and 3D user interfaces consisting of stereoscopic projections and tracked input devices are rarely adopted by ordinary users. The success, both in research and commercial applications, of recent touch-based interfaces raise an interesting possibility. Can the immediacy, control, and expressiveness of recent touch-based natural interfaces be applied to 3D problems?"* [24]

I wanted to answer this question. But before that, several issues had to be dealt with. First, a suitable cooperation partner had to be found. As described earlier, a museum in Weimar was ideal. I needed access to an unbiased audience and topical expertise. Second, we would have to agree on a feasible concept and clarify responsibilities. Subsequently, the system would have to be developed and implemented before the final installation could be evaluated in its real-world environment. Finally, some small adjustments could

be made and larger improvements or augmentations should be discussed.
A museum was found, concepts were made and a TUI or an alternative concept for interaction were required. The *SMSlingshot* already combines a handheld device with 3D interaction to some extend. It is a tangible device, which enables a user to splat short massages onto a facade [13]. The device's affordance is clear, since most people are aware of the functionality of both a phone-sized keypad and a slingshot. Nevertheless, the device can only be used by one user at a time. This is where *Shared Encounters* come into play. There are different types of interrelated spaces, which offer different grades of interaction between a user and either the interface or others [12]. In course of my work, those two key concepts will reappear in more detail.

In the end, my answer was using the most intuitive device there is: a user's body itself.

My focus lied more on the presentation than on the administration software, because it will be used most of the time. Nevertheless, I implemented the whole system to be as versatile as possible and to allow others to use the system almost anywhere. It is not a customized solution for this one installation.

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