UCLouvain

LOUVAIN School of Management

Louvain School of Management

Gestural interaction on spherical display

Elicitation study

Auteur·e(s) : Quentin Lalou
Promoteur·rice(s) : Jean Vanderdonckt
Année académique 2023.-2024.
Master [60] : Business Engineering
Schedule : Daytime schedule

Acknowledgement

First of all, I would like to express my deepest gratitude to Prof. Jean Vanderdonckt, my master thesis supervisor, for his invaluable knowledge and insight throughout the completion of this thesis. He offered me a unique opportunity to perform research on these original topics and helped me to fulfill the goal of the study.

I am also profoundly grateful to Pufferfish Display and its employees for their participation and for allowing me to use their equipment for my study. Their friendliness and cooperation made the research process much smoother and more enjoyable. Their support was crucial in the successful execution of this project.

Abstract

This thesis presents an elicitation study conducted on a spherical touchscreen with 13 participants. The study focused on 25 referents and resulted in the collection of 325 unique gestures. Each of these gestures was classified and categorized to identify patterns and preferences in user interaction. The analysis revealed a clear dominance of one-finger gestures among the participants. Additionally, the study identified certain referents that exhibited exceptionally low agreement among participants, suggesting areas where intuitive gesture design is more challenging. Furthermore, the study highlighted the specific significance of the pole location on the spherical touchscreen, as it played a particular role for some of the participants oriented and executed their gestures. These findings contribute significantly to the understanding of user interaction with spherical touchscreens, providing valuable insights that can inform the design of more intuitive gestures for spherical display technologies.

Contents

Chapter 1

Introduction

1.1 Context

In recent years, touchscreen technology has revolutionized the way humans interact with digital devices, becoming an integral part of everyday life. From smartphones and tablets to interactive kiosks and automotive interfaces, touchscreens offer intuitive and versatile input methods that enhance user experience. However, the majority of research and development in this field has focused on flat, rectangular screens, leaving a gap in understanding the potential and challenges associated with non-traditional display forms, such as spherical screens. This thesis will focus on this type of device, and perform an elicitation study on a sphere provided by the company PufferFish display [5]. The study could only be conducted to the relative of the company and on a very short scale of time, which limited the diversity of the participants. Nonetheless, the direct access to the sphere and its functionalities allowed us to gather data of high value.

These spherical interfaces have potential applications in various domains, including public display technologies, educational purposes and also video games. One of the primary uses is for interactive displays of planetary models, allowing users to explore and interact with maps in an educational context. This can enhance learning experiences by providing a more immersive and engaging way to understand celestial bodies and their characteristics.

1.2 Motivation

The spherical touchscreens present an opportunity to explore unique interactions. Nonetheless, the implementation and optimization of touch interaction on spherical surfaces pose significant challenges, particularly when designing the gesture for actions.

The motivation behind this study comes from the need to close the gap in existing research by investigating how users interact with spherical touchscreens. Understanding these interactions can provide valuable insights into designing more effective and user-friendly spherical interfaces. The primary objectives of this research are to classify user gestures on spherical screens, analyze the frequency and preference of these gestures for various referents, and evaluate the consistency and effectiveness of these gestures using metrics such as agreement score, agreement rate, goodness of fit, and thinking time.

1.3 Objectives

The objective of this study is to identify the most effective and intuitive gestures for manipulating a map of the Earth on a spherical touchscreen interface. To achieve this, specific referents have been carefully designed to represent various interaction tasks, such as zooming, rotating, and interacting with objects. A comprehensive analysis will be conducted to evaluate which gestures are most naturally adopted by users, offering insights into user preferences and ease of use.

Moreover, this study aims to generate valuable data that can inform the development of more sophisticated software recognition algorithms. By understanding the nuances of user interactions with spherical touchscreens, we can enhance the accuracy and efficiency of gesture recognition systems. This will not only improve the user experience but also pave the way for more advanced and reliable applications of spherical interfaces in diverse fields such as education.

1.4 Approach

To find the most intuitive gestures for manipulating a map of the Earth on a spherical touchscreen interface, an elicitation study is performed. In this study, participants are asked to perform gestures on a spherical interface designed for various interactions defined as referents. A total of 25 have been chosen for this thesis. These gestures are recorded and subsequently classified. The recorded data includes also the measurement of the time for the participant to choose a gesture, and the rating they attribute to it.

Following the classification, the agreement score and agreement rate will be calculated to assess the consistency of gesture use among participants. Additionally, an analysis of the goodness of fit and thinking time will be conducted. The gestures will then be categorized, and a detailed analysis within these categories will be carried out to identify patterns and preferences.

1.5 Outline of the thesis

This thesis is organized into five main chapters :

- **Chapter 2 : Related Work** This chapter reviews existing literature and previous research relevant to spherical touchscreens, but also more generally about flat-touch screens and gesture-based interactions.
- **Chapter 3: Elicitation study** The chapter outlines the research design and procedures used in the study. It details the elicitation study process, the device used, data collection, and participant sociodemographic data.
- **Chapter 4: Results and Discussion** This chapter presents the findings from the elicitation study and provides a detailed discussion of the results. It includes an analysis of the most intuitive gestures, agreement metrics, and comparisons of different categories.
- **Chapter 5: Conclusion** The final chapter summarizes the key conclusions drawn from the study. It also outlines potential areas for future research and development, suggesting ways to advance the study of spherical touchscreens and gesture recognition.

Chapter 2

Related Work

This chapter reviews existing research relevant to the study of gestures on spherical touchscreens, comparing them with interactions on flat and vertical display surfaces.

2.1 User-Defined Gestures for Surface Computing

Before considering looking at work of spherical display, let's consider the research on a flat display, which is much more rich. The article WOBBROCK, Jacob O.; MORRIS, Meredith Ringel; WILSON, Andrew D 2009 [13] is an elicitation study that collected over 1080 gestures and developed a taxonomy for the gestures. The study introduces an approach to designing tabletop gestures by eliciting gestures from non-technical users, focusing on how users intuitively perform actions rather than relying on designer-created gestures. A total of 27 commands were asked of the 20 participants, using both one and two hands.

The paper made several discoveries :

- Users generally did not differentiate gestures based on the number of fingers used.
- One-handed gestures were preferred over two-handed ones.
- Desktop paradigms significantly influenced users' mental models, with many gestures imitating usual desktop interactions.
- Some commands showed low agreement among users, indicating a need for supplementary on-screen widgets, like the command **Undo**, **Task switch**, **Next**, **Cut** etc. Figure 2.1 shows the agreement for 1 and 2 hands.

The interest of this study is clearly the user-based gesture definition method and its taxonomy, which will be used later in the thesis.

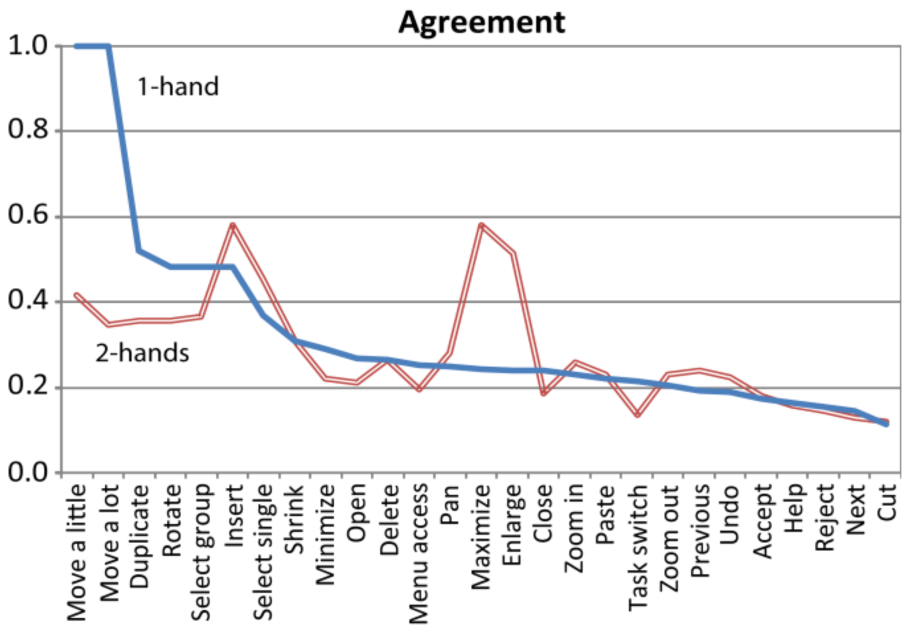


Figure 2.1: Agreement for each referent sorted in descending order for 1-hand gestures. Two-hand gesture agreement is also shown for [13].

2.2 GlobalFestival: Evaluating Real World Interaction on a Spherical Display

WILLIAMSON, Julie R.; SUNDÉN, Daniel; BRADLEY, 2015 [10] addresses a lack of research into touch interactions for spherical displays and their use in real-world settings, particularly in public spaces and aims to bring more insight into the research field.

The study focuses on the real-world deployment of an application called GlobalFestival on a spherical display. This application is tested with two different touch interaction techniques: either users could both spin and tilt the content on the display, or they could only spin the content. Here are the main advances of the article :

- The paper brought insights into how users approach and move around the spherical display.
- Evaluation of how the two versions of the application impact user interaction.
- An analysis has been made on how the spherical display supports social interaction, given its unique form factor.

The paper, despite studying the interaction of several people with one sphere, gives a good understanding of how the device can be applied in public spaces. Having a good understanding of the use of the sphere will allow us to design coherent referents during the study. It also addresses the issue of multi-user interaction (see also [1] and [12]). Here, the study will be oriented toward one user only, but considering the applications of the sphere, actions have to be designed such that they can be performed by more than one user, or by a succession of independent users. This also shows the necessity to have intuitive gestures for the sphere since users will usually not be introduced to the functionality of the spherical touch screen in this particular application.

2.3 Adults' and Children's gestures on Interactive Spherical Displays

On the other hand, the educational purpose of the device also raises the interest to investigate how children and adults will interact with the device. SONI, Nikita; GLEAVES, Schuyler *et al.* 2019 and 2020 ([8] and [7]) conduct studies comparing the gestures performed by adults and children, and compare them. More interesting, they also compare their results with previous studies performed on a flat screen.

To do so, elicitation studies were performed on a group of children (from 7 to 11 years old) and adults. Here are the main findings :

- The spherical form factor significantly shaped users' mental models. Participants viewed the spherical display as responding similarly to real-world spherical objects, such as globes.
- Conceptual Models: Users' interactions with the sphere were influenced by their prior experiences with touchscreens and their perceptions of the sphere's affordances.
- The spherical display's form factor impacted gesture design. Users were more inclined to use multi-finger or whole-handed gestures on the sphere compared to the flatter tabletops as shown on the figure 2.2. It also reveals differences in gesture characteristics between spherical displays.

Since differences have been shown between flat touch screens and spherical touch screens, it implies the design of different gestures for an efficient use of the device. The thesis should provide more information about which gesture is the most intuitive for users.

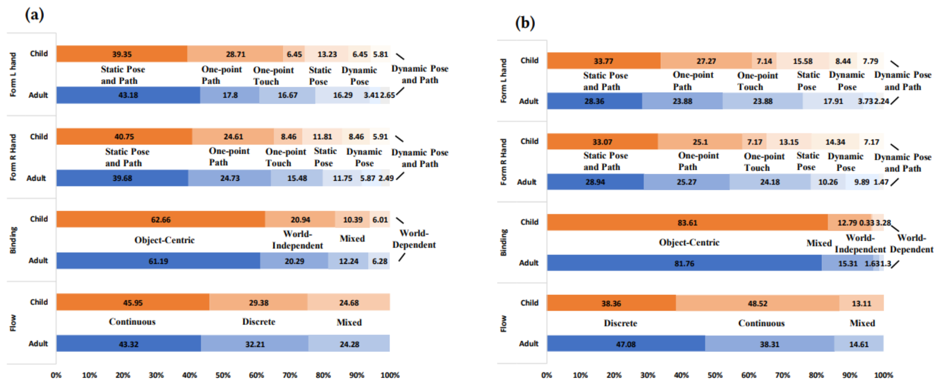


Figure 2.2: : Results of gesture classification for our full set of referents in (a) and only the traditional touchscreen referents in (b), from [8].

2.4 Additional works

Other studies on spherical displays were performed and are cited in this thesis ([2], [3], [4], [14]). Despite being less relevant for an elicitation study, they are still worth keeping in mind because they provide useful context.

Chapter 3

Elicitation study

This chapter outlines the methodology employed in the elicitation study, detailing the experimental design, data collection procedures, and information about the participants.

The chapter begins with a description of the device used, followed by the set of referents and the reasons for their choice. Subsequent sections detail the data collection procedures, as well as the process of the experiment. The chapter concludes with a discussion of the sociodemographic data collected on the participants and the potential bias associated with it.

3.1 Device

The device used for the elicitation study is a *Puffer Touch 750mm* from the firm Pufferfish displays [6]. The sphere has a 750mm diameter and is fixed on a cylindrical support such as the entire device has a height of 1582mm. The light source is a diode laser of class 1 projected on the plastic sphere. The software is able to detect and track 64 touch on the screen, allowing complex gestures like panning or pinching using several hands and fingers. The OS of the sphere can track the contact points, and associate it with fingers. With that recognition technology, the device can register panning gestures, allowing drawing or dynamic poses with the hand. A picture of the device is shown on the figure 3.1.

The in-built software PufferBuild is able to design animations like videos, shifting of rotating objects, but also interactions such as zooming on a particular surface, or using an interface such as a menu or a set of buttons. All those characteristics will be used in the study to make the most interactive and realistic referents possible. Some actions will be animated during the gesture so the participant will have instant feedback on the meaning of the interaction.

Figure 3.1: A model of the device used for the experiment [6].

3.2 Set of referents

Since the device will be used for educational purposes for planets, it was natural to use a map of the heart as a background for the sphere. Every referent is based on this earth template. Also, the actions were designed in order to allow full use of the interactions on the sphere similar to educational games on tablets or computers.

First of all, a set of referents is designed to navigate on the sphere. It includes the rotation on the 3 Cartesian axis, but also the zoom in and zoom out in a spot of the map. The different axes are shown in the appendix (6) to avoid any confusion. It allows the user to change the state of the sphere and move to different locations.

On the other hand, the device should have an option to enhance mote interaction with the map itself, through access with a small menu or some kind of interface. It is why an action **Open the menu** was added. Also, we could imagine the will of the user to change the filter of the map, like passing from a topological map to a political map for example. Doing so allows the device for educational purposes for more than one field of knowledge. With the same purpose, an action **Forward/Backward in time**.

We could imagine a map of the world with borders changing with time, or meteorological data evolving through the globe. Also, an option **Reset** was designed to offer the option to undo every modification brought to the sphere, allowing a new user to enjoy the educational program without having previous tasks already done. All those options are interface-oriented.

We would like that the user can interact with particular places. To do so, a set of referents using landmarks was created. Place, select, move, go to, name or delete landmarks allows different programs such as guessing different locations, spotting different places, etc.

But educational programs could require more than only landmarks, and use larger spots with different shapes. It's why an action **Select an area** has been added, to highlight large locations on the globe like continents or countries. In the same idea, 2 actions related to paths are included. We could imagine that the user can draw the path of an airplane, or a chain of mountains with this functionality. It's also one of the advantages of the device since it can track points and associate them with "fingers", allowing panning gestures and complex dynamic motions.

Finally, since the sphere is designed for planets, referents linked with geographical coordinates should be pertinent. To do so, interactions with meridians and parallel are here to enhance the use of a map projected on a sphere. The same set **Select/Move/ Delete** are present for both of the coordinates.

Overall, 25 gestures were asked of the participants. Here is the list of every referent:

1. **Rotation X**
2. **Rotation Z**
3. **Rotation Y**
4. **Zoom in**
5. **Zoom out**
6. **Open the menu**
7. **Change the type of map**
8. **Forward/Backward in time**
9. **Reset**

10. **Select an area**
11. **Draw a simple path**
12. **Draw a complex path**
13. **Place a landmark**
14. **Select a landmark**
15. **Move a landmark**
16. **Delete a landmark**
17. **Name a landmark**
18. **List of landmarks**
19. **Go to a landmark**
20. **Select a meridian**
21. **Move a meridian**
22. **Delete a meridian**
23. **Select a parallel**
24. **Move a parallel**
25. **Delete a parallel**

Each of those referents is associated with either an animation or a succession of 2 images (initial state and final state) projected on the sphere using the software PufferBuild. Each referents are shown in the appendix 6 with a description and a 3D sphere showing the expected result on the device.

3.3 Experiment

In this section, we will describe the process of the experiment and how each participant has to fulfill their tasks. This includes the preliminary survey and the experiment itself.

3.3.1 Preliminary survey

Before the experiment takes place, every participant is asked to fill out a consent form that guarantees their anonymity. As such, a random 4-digit number is attributed to them and the data are associated with this new ID. They are also informed that they can stop the experiment whenever they want without any consequences, and no reasons are required. The consent form is shown in the appendix 6.

After that, the participant has to complete a sociodemographic survey asking, for different information such as their gender, their age, and their job. The second part of the form asks them to guess their usage frequency on different devices : computers, flat touch screens (smartphones or tablets), and spherical touch screens. They are asked to give a number between 0 (= don't use them at all), and 5 (=use them very often). The survey is available in the appendix 6.

3.3.2 Procedure of the experiment

When the preliminary survey is filled, the participants are brought to the sphere. A camera is turned on such that it can record the gestures of the participant but not its face, in order to guarantee its anonymity according to the consent form. A picture of the setup is shown in the figure 3.2.

Before any referent is shown, an explanation of the context of the experiment is given. The procedure of the study is explained, along with the tasks that are asked of them. A few seconds are given to the participant to interact freely with the device so they can get used to it. They are also informed that there are no limitations to the gestures they can perform. Any actions, such as drawing symbols, and using both hands or several fingers are allowed. Furthermore, they can modify the gesture chosen for a referent if they are more comfortable with it.

Since some actions are symmetrical (like rotations around different axes for example), the referents are shown by a group of coherence. So every rotation is shown successively, as such for the different zoom, coordinates/landmark interactions or path actions. A set of different random numbers is drawn to determine the order of presentation to avoid any bias.

When the order of presentation is well defined, the experiment begins. Each reference consists of a small animation or 2 different states (initial and final) shown to the participant. Once the action is shown, the experimenter starts the timer. Once the participant chooses a gesture and does it on the screen, the timer is stopped and the thinking time is encoded, as long as the gesture is chosen. After that, an evaluation from 0 to 10 is asked about how the participant would rate the gesture. This note will be further called the goodness fit. This process is then repeated for each referent until the end of the experiment.

Figure 3.2: Set up of the experiment, with a participant using the sphere.

3.4 Participants

Since the device was available only at the PufferFish office, and due to the limited time given to make the experiment, the study was conducted on only 13 participants. Usually, this kind of study is performed on at least 20 participants. Furthermore, each of them is either employed or related to the company and has already seen the device and interacted with it. This is a huge bias since the device is destined for educational purposes, mainly for people using a spherical touch screen for the first time. As such, the analysis has to be conducted with this bias in mind and we expect similar gestures since some of the referents are already used by the employees.

Among the 13 participants, 9 are men and 4 are women with job activity dispatched between technology and office work. This includes IT, marketing, finance, management... The age of participants are aged from 24 to 55, with a mean of 39. It's a relatively old population considering the educational application of the sphere. The result of the survey is shown in the figure 3.3.

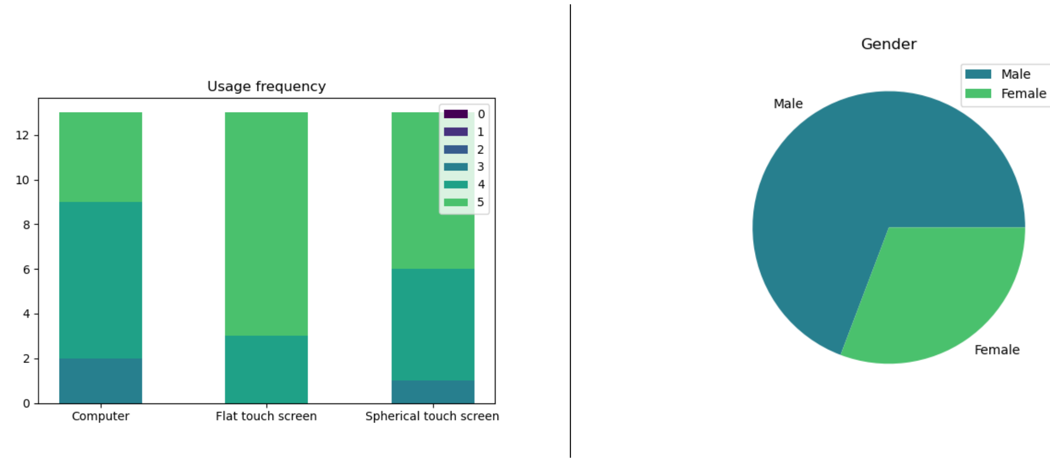


Figure 3.3: Usage frequency and gender of the participants.

Figure 3.3 shows clearly that every participant is already used to every device. Indeed, none of them has a rate below 3. The usage of touch screens is already well known and we expect the participants to use gestures that they already know. The usage of the computer is also very present, which might also affect the data.

Chapter 4

Results and discussion

This chapter presents the findings of the elicitation study and provides a comprehensive discussion of the results in the context of the research objectives. The primary aim of this chapter is to interpret the data collected from the participants.

First, the classification of each gesture is explained, followed by a discussion of the most frequent gesture for each referent. Next, two metrics, the agreement score and the agreement rate, are introduced to understand the extent to which participants used the same gestures. The goodness of fit and thinking time is then presented and discussed, including a comparison between different metrics. Finally, each gesture is categorized according to Wobbrock et al. (2009) [13], and the results are examined within these categories.

4.1 Classification of the gestures

The experience gathered a total of 325 gestures. Since the analysis of each one is impossible, they are all classified. A total of 30 classes have been identified and are reported in table 4.1 with a description associated with each one.

The data collected using this system of classification are shown in the appendix 6. A first observation can be done by looking at the data for a series of symmetric referents, like **rotation**, **zoom** and the referents linked to **coordinates**, where the data are the same for every type of motions, so each participant use the same gesture for every **rotations**, and so on for the other referents identified.

We see a lot of gestures often used on flat screens, such as the pan and the tap. But there are also more original gestures like *press and pan (2 fingers)*, where one finger is static and the other one is moving. A lot of motions were also expected to open an interface with a previous gesture, such as used for the referent **Open menu**, followed

Gesture	Description
Tap	Discrete one-finger touch
double tap	Discrete one-finger touch 2 successive times
triple tap	Discrete one-finger touch 3 successive times
tap (2 fingers)	Discrete two-finger touch
specific tap	Discrete one-finger touch at a specific location (except the pole)
double tap (particular)	One-finger touch 2 successive times on a particular location of the map
successive tap	Discrete one-finger touch on successive locations
tap the pole	Discrete one-finger touch on the pole
triple tap the pole	Discrete one-finger touch 3 successive times on the pole
pan	Continuous one-finger touch doing a linear displacement
pan (4 fingers)	Continuous four-fingers touch doing a linear displacement
pan (draw)	Continuous one-finger touch describing a non-linear path
pan (circular)	Continuous one-finger touch describing a circular path
press and pan (2 fingers)	One-finger static touch and a one-finger dynamic touch with the other finger
pan to the pole	Continuous one-finger touch describing a path to the pole
drag and drop	Continuous one-finger touch on the object describing a path to another location
Pinch	Continuous two-finger touch with internal or external direction
pinch (2 hands)	Continuous one-finger touch on each hand with internal or external direction
pinch (3 fingers)	Continuous three-fingers with internal or external direction
press and hold	One-finger touch maintained during at least 1 second
hold the pole	One-finger touch on the pole maintained for at least 1 second
hold and swipe	Continuous one-finger touch with a quick external motion
5 fingers hold	Five-fingers touch maintained during at least 1 second
2 hands hold and swipe	Continuous two-hands touch with a quick external motion
clock motion	Metaphorical motion imitating a turning clock (2 directions)
interface use (button)	Tap on an expected button to do the referent
interface use (menu)	Tap on an expected menu to do the referent, previously opened by another gesture
interface use (line)	Pan on an expected line to do the referent, previously opened by another gesture
keyboard use	Successive tap on a keyboard previously opened by another gesture
border draw	Continuous one-finger touch describing a path following the border of a country, less hazardous than pan (draw)

Table 4.1: Table of the classification of each gesture.

then by a single tap. Those motions are refereed as *interface use* with the expected interaction. For example, *interface use (button)* expect a first motion to show a small button, then a simple tap on it. We see a clear correlation between this gesture and the kind of interactions that could be done with a computer. The fact that most participants use them frequently must probably be the cause for so much use of that *interface use* gestures.

This classification allows us to analyze the data. The table 4.2 shows which gesture is the most used for each referent. The panning for the 3 rotations seems to be the most popular, along with the pinch for the zoom in/out. It was expected since this kind of gesture is often associated with navigation on smartphones and tablets. On the other hand, we see gestures that use the particular shape of the sphere such as *hold the pole*, consisting of maintaining contact with the pole of the sphere. It has been the most popular gesture for the referent **reset**. A reason for this is the accessibility of this area independently from where the participant is standing around the sphere, but it is sufficiently hard to access to avoid pressing it by accident. And so, this location is used as a specific point on the map to have special interactions.

Referent	Most frequent gesture	Number of occurrence
Rotation Z	pan	11
Rotation X	pan	11
Rotation Y	pan	11
Zoom in	pinch	11
Zoom out	pinch	11
Open the menu	press and hold	6
Change the type of map	interface use (menu)	7
Forward/Backward in time	interface use (line)	6
Reset	hold the pole	8
Select an area	press and hold	4
Draw a simple path	pan (draw)	11
Draw a complex path	pan (draw)	11
Place a landmark	press and hold	5
Select a landmark	tap	9
Move a landmark	drag and drop	12
Delete a landmark	interface use (button)	7
Name a landmark	keyboard use	12
List of landmarks	press and hold	4
Go to landmark	specific tap	13
Select a meridian	pan (draw)	10
Move a meridian	drag and drop	12
Delete a meridian	interface use (button)	5
Select a parallel	pan (draw)	10
Move a parallel	drag and drop	12
Delete a parallel	interface use (button)	5

Table 4.2: Table showing the most frequent gesture and its number of occurrences.

Another observation can be made for the **Name a landmark** action, which is almost exclusively done with a *keyboard use*. Indeed, almost all participants were expecting a keyboard on the screen to write down the name. No proposition for symbols or handwriting was made.

Another high occurrence can be seen for each referent including the **Move** actions that have the drag and drop gesture. Here as well, the similarity with computers is clear since those actions are very frequent, typically for the generation of files.

4.2 Agreement

In order to evaluate how the gestures are common between the participants, we will use a set of 2 indicators. First, the agreement score, defined by Vatavu and Jacob O. Wobbrock 2022 [9] :

$$AS = \sum_{P_i \subseteq P} \left(\frac{|P_i|}{|P|} \right)^2$$

where $|P|$ is the total number of proposal and $|P_i|$ the number of proposeal for the i^{th} class.

To complete this measure, another metric will be used, the agreement rate, which is defined as follows (from Vatavu and Jacob O. Wobbrock 2022 [9]):

$$AR = \frac{\sum_i \sum_{j \neq i} [p_i = p_j]}{N(N-1)}$$

where N is the number of participants and p_i the proposal for the i^{th} participant.

The results are shown in the figures 4.1 and 4.2. The agreement score goes from 0.19 to 1, and the agreement rate from 0.13 to 1. Since the number of participants is low and already know the device, the agreement score is overall very high. Indeed, more than half of the referents have a score above 0.5. Nonetheless, some referents have relatively low considering the participants. Referents like **select an area**, **delete coordinates (meridian/parallel)**, or **open a menu/list** are far from a common agreement.

We can also observe in the figures the presence of flatness on the graphs. It's mainly due to the symmetry of different referents that are used. Indeed, the participants used exactly the same gestures for each **rotations**, for **zoom in/out**, and for every interaction with the **delete a coordinates (meridian/parallel)**.

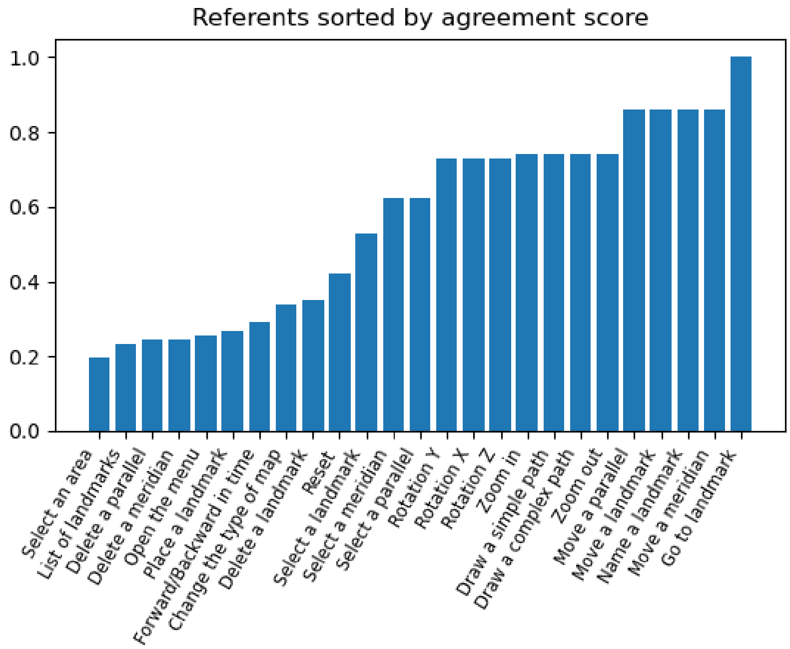


Figure 4.1: Agreement score for each referent.

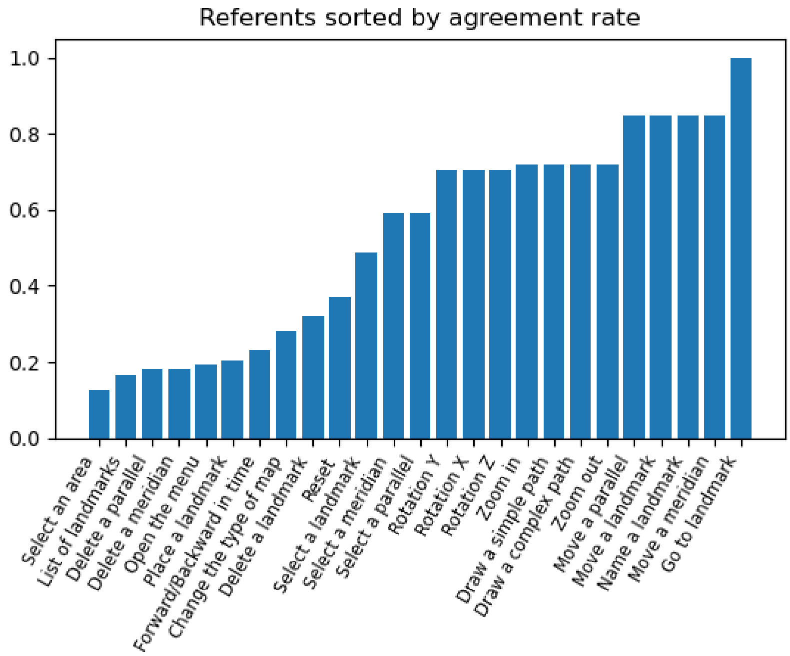


Figure 4.2: Agreement rate for each referent.

4.3 Goodness of fit

Another data that wasn't aborded yet is the goodness of fit. Each participant rated their gesture with a note from 0 to 10. Figure 4.3 shows the average for each referent. The averages range from 6.1 to 9.5, and the standard deviation is from 0.8 to 2.9.

An interesting feature is the absence of equality for symmetric referents. Indeed, the agreement score and the propositions were the same for each rotation. Nonetheless, the participants rate the **rotation Y** with a significantly lower goodness of fit (9.38 for **rotation X** and 8.31 for **rotation Y**). It means that the 3rd referent is different and they do not find the same gestures as for **rotation X** and **rotation Z** adapted. The main difference here is that the Y axis is oriented toward the participant, where X and Z are perpendicular. The participants have to tend the arm to pan correctly the rotation the same way for **rotation X** and **rotation Z**. This extra effort for a similar action on the sphere might explain the loss of goodness of fit for this particular referent.

The same analysis can be done with the **Draw a simple/complex path** and **Select a meridian/parallel** referents. The complex path obtains a slightly lower goodness fit, despite having the same gesture. The difference is even higher between the merid-

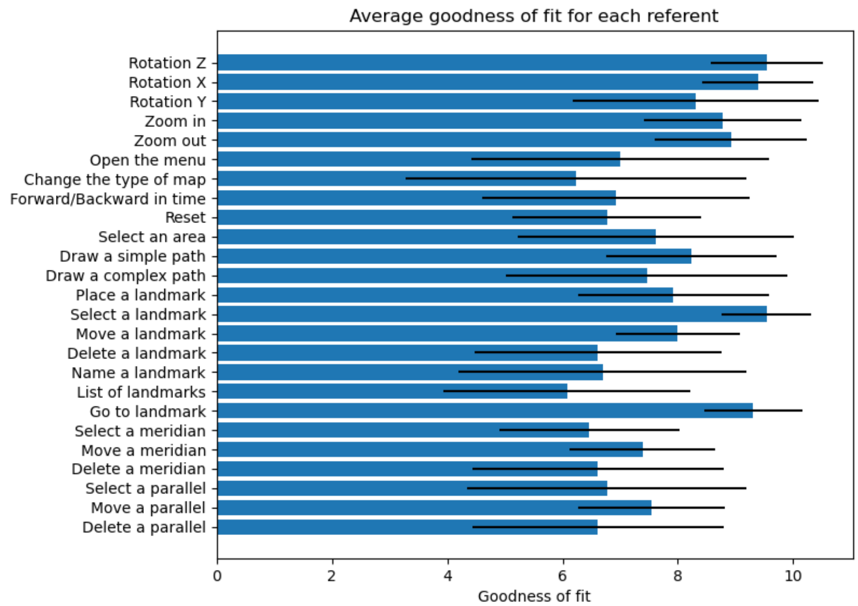


Figure 4.3: Mean of the goodness of fit for each referent, along with the error.

ian and parallel selection. Since most of the motions are panning over the object, the meridian starts and ends at the poles. On the other hand, parallels are all around the globe. Without a clear start and an end to the motion, the gesture seems less adapted and it could explain this disparity.

A comparison between the goodness of fit and the agreement score is shown in figure 4.4. This graph does not show any correlations between the 2 metrics.

4.4 Thinking time

During the experiment, the thinking time for each gesture was measured. Figure 4.5 shows the average thinking time for each referent. The average range from 5 to 24s and the standard deviation is from 1.5 to 15.1s.

The thinking time has a very high standard deviation for some referents. Even higher than the average itself, which indicates that participants have a very wide range of thinking time, even for most basic actions like **rotations** or **zoom**. Nonetheless, their average is quite low, which means the standard deviation is increased by a few

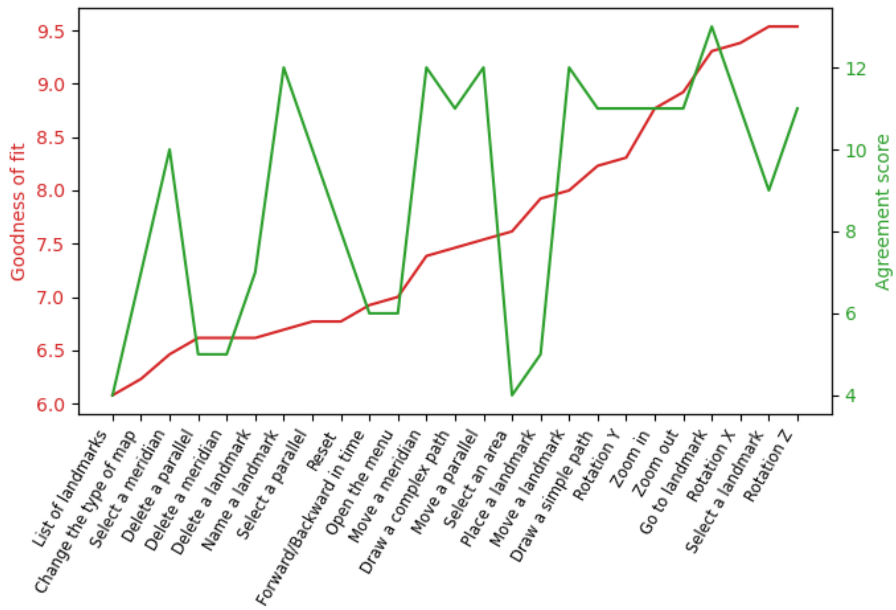


Figure 4.4: Comparison between the goodness of fit and the agreement score, sorted according to the goodness of fit.

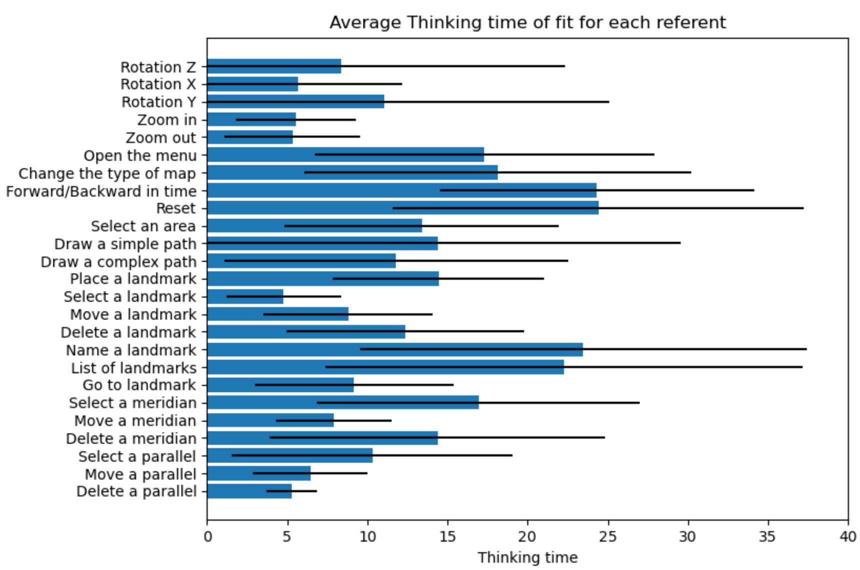


Figure 4.5: Thinking time (in s) for each referent, along with the error.

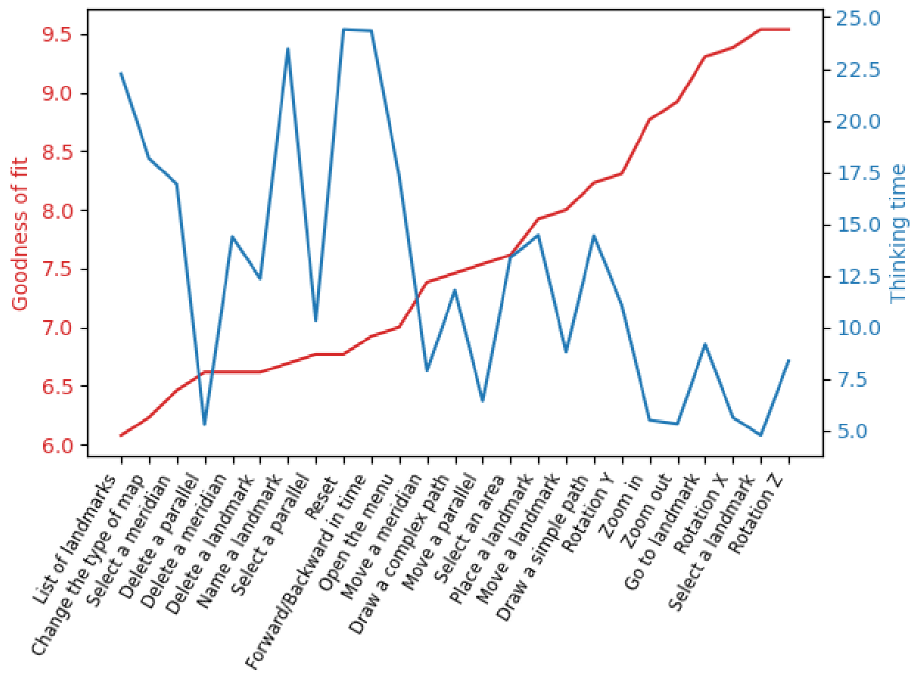


Figure 4.6: Comparison between the goodness of fit and the thinking of time, sorted according to the goodness of fit.

participants with very long thinking times.

On the other hand, the longest time is obtained for the actions **Forward/Backward in time**, **reset**, **name a landmark** and **list of landmark**. Those referents seem less intuitive, and most of the candidates give a gesture expecting an interface like a button or a menu to execute the referents.

Once the 2 metrics are gathered, a comparison can be done between them, as shown in the figure4.6. It shows clearly that referents with a high goodness of fit have relatively low thinking time, which means the participants find quickly the gesture that is the most coherent according to them. The opposite is less true, even if most of the rerents with a goodness of fit below 7.5 have a thinking time above 15s, some of them have a very low thinking time, close to the minimum value measured.

4.5 Categories

In order to obtain more information about the gesture chosen, each gesture will be categorized, according to the taxonomy developed by Wobbrock, Jacob O. and Morris, Meredith Ringel and Wilson, Andrew D. 2009 [13].

A total of 16 categories has been analyzed, divided into 4 domains :

- The **Form** describes the pose of the hand and its motion on the touch screen.
- The **Nature**, focusing on the meaning of the gesture.
- The **Binding**, describing where the gesture is applied.
- The **Flow**, indicating if the action is executed after or during the gesture.

The description of each category is shown in the table 4.3.

	TAXONOMY OF SURFACE GESTURES	
Form	static pose	Hand pose are held in one location.
	dynamic pose	Hand pose changes in one location.
	static pose and path	Hand pose are held as hand moves.
	dynamic pose and path	Hand pose changes as hand moves.
	one-point touch	Static pose with one finger.
	one-point path	Static pose & path with one finger.
Nature	symbolic	Gesture visually depicts a symbol
	physical	Gesture acts physically on objects
	metaphorical	Gesture indicates a metaphor.
	abstract	Gesture-referent mapping is arbitrary.
Binding	object-centric	Location defined w.r.t. object features.
	world-dependent	Location defined w.r.t. world features.
	world-independent	Location can ignore world features.
	mixed dependencies	World-independent plus another.
Flow	discrete	Response occurs after the user acts.
	continuous	Response occurs while the user acts.

Table 4.3: Table describing each category for the gestures (from [13]).

The categorization requires an entire review of each class of gestures put into the context of the referent. Indeed, a double tap for a referent like **Open the menu** can be categorized differently than a double tap on a referent like **Select a landmark**, since both of the gestures are the same, but the context is different since the first one is a double tap on a random place around the world and the second is centered on an object.

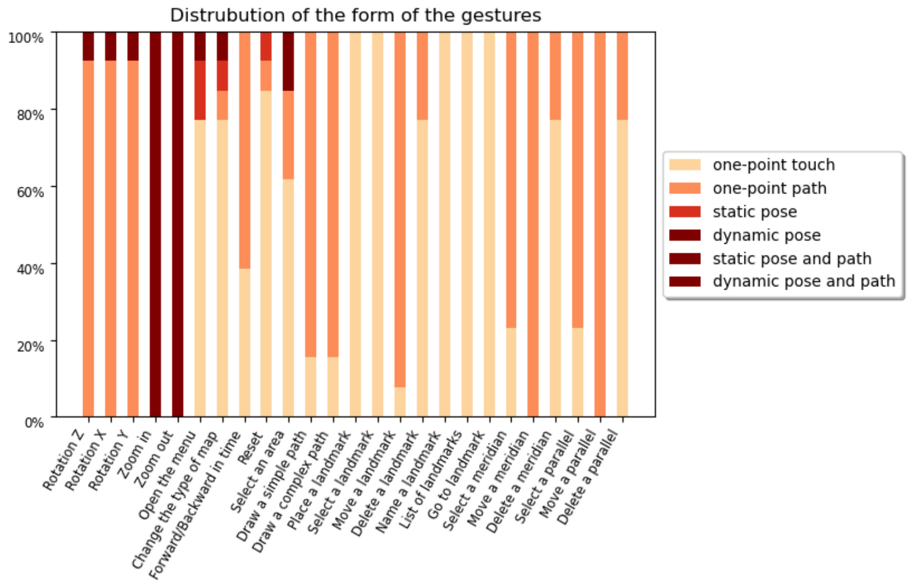


Figure 4.7: Distribution of the form of the gestures for each referent.

4.5.1 Form

Figure 4.7 shows the distribution of the **Form** category for every referent. It shows a clear dominance of the one-point touch/path for every referent (288 gestures on the 325 collected), with only one exception for the referents **zoom in/out** coming from the pinching. The participants tend to use only 1 finger to interact with the sphere, despite varying with touch and paths.

4.5.2 Nature

In the figure 4.8, the nature of the gesture is shown. Here, the referents are split into 2 kinds of distributions : the ones with a majority of abstract nature and the ones with a majority of physical nature. Indeed, each referent of navigation (**rotations** and **zoom**) are gestures mostly of a physical nature. Indeed, the gesture seems more intuitive to displace the map as the participant acts physically on it. The same pattern is observed for the **move** and **select** actions. The participants tend to drag and drop the objects they have to move and act physically on the objects they would like to select. The article [7] also found this trend.

On the other hand, the actions requiring to **delete** or **place** an object are much more abstract, as such with actions changing the entire map like **reset** or **change the type of map**. Most of the participants expect an interface that has no particular meaning

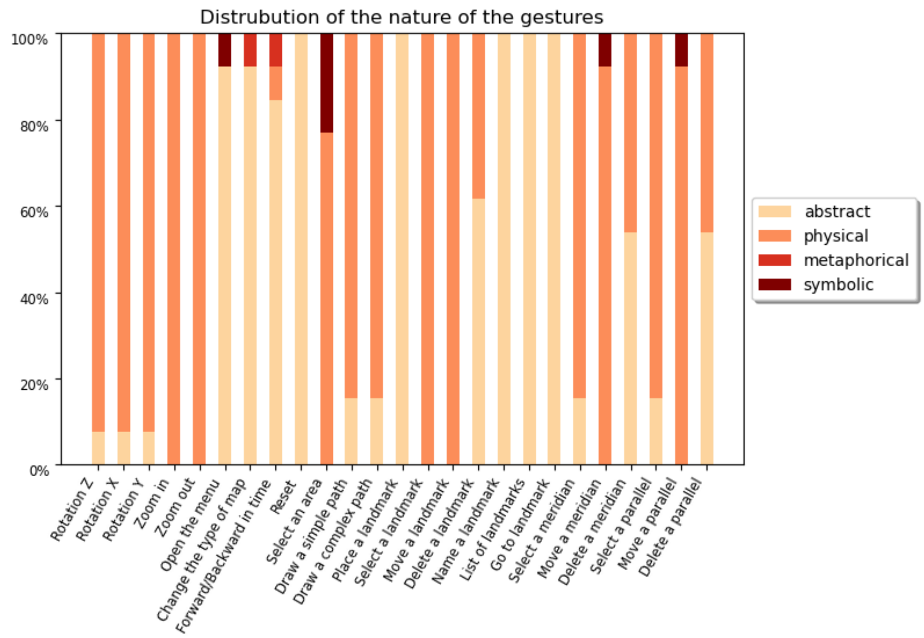


Figure 4.8: Distribution of the nature of the gestures for each referent.

for the gesture. It is also the same observation for gesture opening **menu** or **list**, where candidates don't find meaning to it.

Only a very small portion of gestures have a symbolic or metaphorical nature. Those kinds of gestures were not popular among the set of participants.

4.5.3 Binding

The binding distribution shown in the figure 4.9 indicates a clear trend for the navigation referents, and a dominance of the object-centric binding for most of the gestures implying a **landmark** or **coordinates**. It was expected since the referent requires a direct interaction with the object. On the contrary, actions like **open the menu**, **open a list of landmarks**, **Forward/Backward in time** and **Change the type of map** have distributions with no clear majority. These referents were also the ones with a low agreement score, which means the participants did not agree on which gesture to choose but also on what kind of motion should be used.

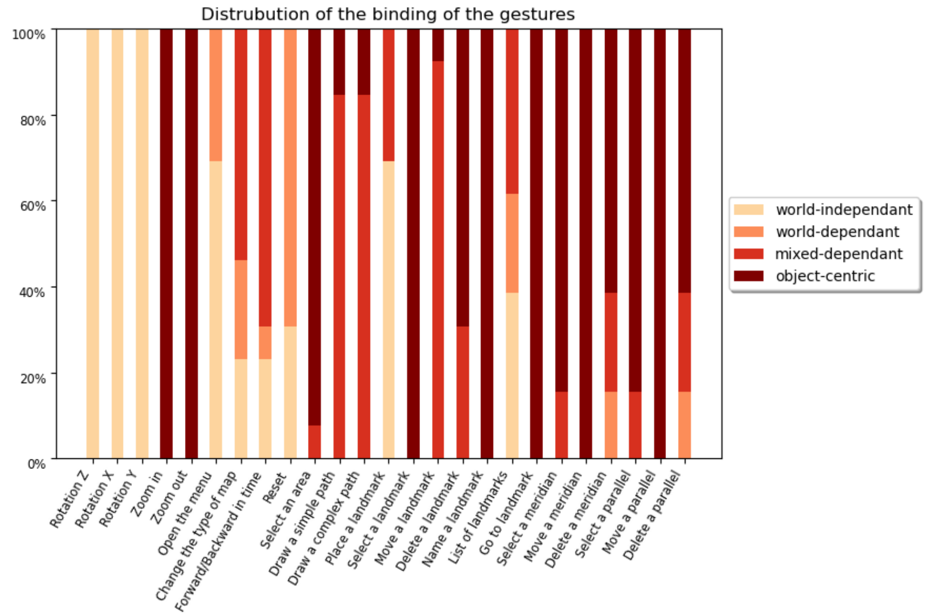


Figure 4.9: Distribution of the binding of the gestures for each referent.

4.5.4 Flow

Finally, the figure 4.10 shows the distribution of the flow of the gestures for every referent. Similarly to other categories, the navigation referents have a clear majority with continuous gestures. Here, the only referents with no clear trend are the **forward/ backward in time** and **select an area**. Except for those, participant seems to have a common flow for the gesture for the referents.

4.5.5 Summary

The analysis reveals that participants generally favored simple, direct gestures that mimic physical interactions with the sphere. Navigation tasks were particularly intuitive, with high goodness of fit scores and low thinking times. However, abstract tasks, particularly those involving interface-like interactions, were less intuitive and required more cognitive effort.

The gesture categorization shows a clear preference for physical, object-centric gestures with continuous feedback, particularly for tasks involving direct manipulation of objects on the sphere.

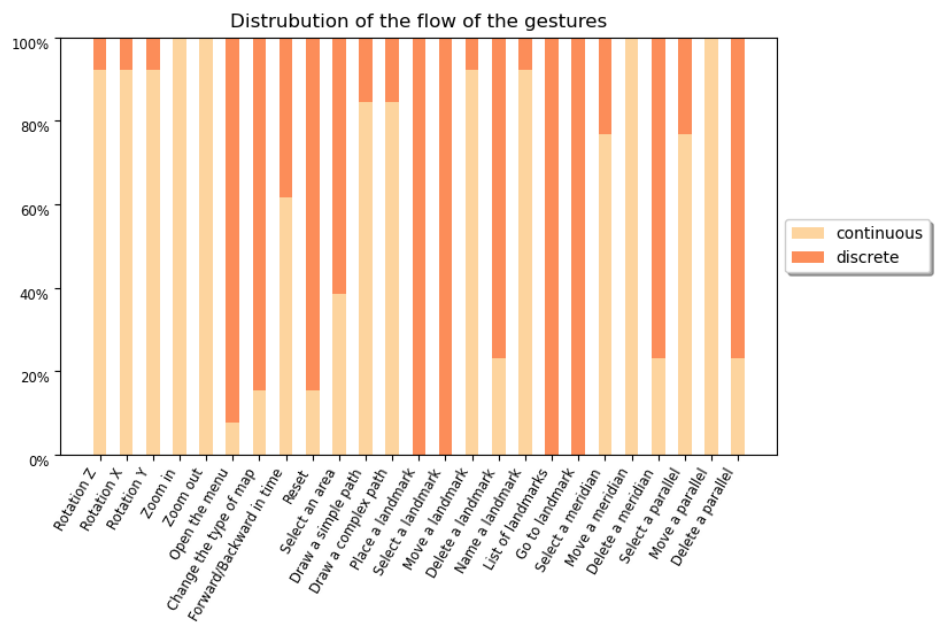


Figure 4.10: Distribution of the flow of the gestures for each referent.

Chapter 5

Conclusion

5.1 Main findings

Here are the main conclusions of the analysis of the results.

5.1.1 Dominance of one-finger gestures

The thesis has shown that most of the gestures have the form of a one-finger gesture, describing either a touch or a path on the surface. This contrasts with other papers like [7], where gestures with the whole hand are usually enhanced by the use of a spherical touch screen. This is certainly due to the bias linked to the participants and their frequent use of computers. Papers like [13] show the tendencies to use desktop interactions, which is further enhanced when participants are used to those tasks on computers.

5.1.2 Referents with low agreement

Despite having a small group of participants regularly using the sphere, some referents had a low agreement score, especially if we account for the selection bias. In fact, three families of referents can be identified as having bad results for the 2 agreements metrics :

- **Large interaction** (**select an area**, **Forward/Backward in time**, **Change of the type of map**, **Reset**), regrouping every referent that will act on a large location, or the entire map. The average agreement score is 0.31 for these referents, relatively high considering the set of participants. There are various bindings associated with the gesture. We can conclude that the participants do not agree on the dependency on the world in front of a referent with large dimensions.

- **Actions opening a new interface** (**open the menu**, **list of landmarks**) are referents designed to create a small menu to allow more actions. Average agreement score of 0.24. All the referents have gestures with mainly an abstract nature, a one-point touch form, but also no clear binding.

- **Create/Delete an object** (**delete a meridian**, **delete a parallel**, **place a landmark**, **delete a landmark**). We note that the action to move the object is not affected is very intuitive for participants, but they struggle to create an object from nowhere and remove it in a simple way. The average agreement score is here 0.27. Here, gestures have mainly common categories (abstract, discrete, object-centric for deleting actions and world-independent for creating ones and using a one-point touch). The reason for so much trouble in defining a clear gesture is still unknown.

5.1.3 Specific location : the pole

Gestures located on the pole were used on various referents, and are even the most used for the **reset** action (17 gestures among 5 referents, so 26% of the gestures), despite no specificity on the referents shown at this location. The pole seems to have a symbolic meaning for the participants and attribute a particular action to it. Furthermore, this special location is ergonomic for the use of special action since it is reachable while being out of the way for most interactions. This might be a solution for the integration of an additional interface easy to use and intuitive.

5.2 Review

In summary, this thesis conducted an elicitation study that gathered valuable data, enabling us to determine which gestures were most intuitive for users. We also identified referents where users struggled to agree on a common gesture and, through analysis of the collected data, identified probable causes for some of these difficulties, although some grey areas still remain. This is why further investigations on the research field are proposed.

5.3 Future Works

This study has been performed on a small group of participants, with already a good knowledge of the device, which is not a realistic case considering the applications of the device. To obtain more results and confirm the conclusions of the thesis.

The difficulty for participants to identify actions for creating/deleting object is unknown. A study with those referents and a new set of categorizations could be performed to enlighten this.

This thesis was focused on gestures with only one user. Since the device is used in public spaces and for multi-game applications, an elicitation study with multiple users could be designed to gather the same set of referents. It could also be a big advancement relative to other papers like [1].

Bibliography

1. BENKO, Hrvoje; WILSON, Andrew D.; BALAKRISHNAN, Ravin. Sphere: multi-touch interactions on a spherical display. In: *Proceedings of the 21st Annual ACM Symposium on User Interface Software and Technology*. Monterey, CA, USA: Association for Computing Machinery, 2008, pp. 77–86. UIST '08. ISBN 9781595939753. Available from DOI: 10.1145/1449715.1449729.
2. LI, Zhengqing; MIYAFUJI, Shio; SATO, Toshiki; KOIKE, Hideki. OmniEyeball: Spherical Display Embedded With Omnidirectional Camera Using Dynamic Spherical Mapping. In: *Adjunct Proceedings of the 29th Annual ACM Symposium on User Interface Software and Technology*. Tokyo, Japan: Association for Computing Machinery, 2016, pp. 193–194. UIST '16 Adjunct. ISBN 9781450345316. Available from DOI: 10.1145/2984751.2984765.
3. LI, Zhengqing; MIYAFUJI, Shio; SATO, Toshiki; KUZUOKA, Hideaki; KOIKE, Hideki. OmniEyeball: Spherical Display Equipped With Omnidirectional Camera And Its Application For 360-Degree Video Communication. In: *Adjunct Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology*. Berlin, Germany: Association for Computing Machinery, 2018, pp. 33–35. UIST '18 Adjunct. ISBN 9781450359498. Available from DOI: 10.1145/3266037.3266092.
4. PAN, Ye; STEPTOE, William; STEED, Anthony. Comparing flat and spherical displays in a trust scenario in avatar-mediated interaction. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Toronto, Ontario, Canada: Association for Computing Machinery, 2014, pp. 1397–1406. CHI '14. ISBN 9781450324731. Available from DOI: 10.1145/2556288.2557276.
5. *PufferFish display main site.* [N.d.]. Available also from: https://www.pufferfishdisplays.com.
6. *PufferTouch, Made to touch. The world's leading touch-enabled spherical display.* [N.d.]. Available also from: https://www.pufferfishdisplays.com/products/puffertouch/.

7. SONI, Nikita; GLEAVES, Schuyler; NEFF, Hannah; MORRISON-SMITH, Sarah; ESMAEILI, Shaghayegh; MAYNE, Ian; BAPAT, Sayli; SCHUMAN, Carrie; STOFER, Kathryn A.; ANTHONY, Lisa. Adults' and Children's Mental Models for Gestural Interactions with Interactive Spherical Displays. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Honolulu, HI, USA: Association for Computing Machinery, 2020, pp. 1–12. CHI '20. ISBN 9781450367080. Available from DOI: 10.1145/3313831.3376468.

8. SONI, Nikita; GLEAVES, Schuyler; NEFF, Hannah; MORRISON-SMITH, Sarah; ESMAEILI, Shaghayegh; MAYNE, Ian; BAPAT, Sayli; SCHUMAN, Carrie; STOFER, Kathryn A.; ANTHONY, Lisa. Do user-defined gestures for flatscreens generalize to interactive spherical displays for adults and children? In: *Proceedings of the 8th ACM International Symposium on Pervasive Displays*. Palermo, Italy: Association for Computing Machinery, 2019. PerDis '19. ISBN 9781450367516. Available from DOI: 10.1145/3321335.3324941.

9. VATAVU, Radu-Daniel; WOBBROCK, Jacob O. Clarifying Agreement Calculations and Analysis for End-User Elicitation Studies. *ACM Trans. Comput.-Hum. Interact.* 2022, vol. 29, no. 1. ISSN 1073-0516. Available from DOI: 10.1145/3476101.

10. WILLIAMSON, Julie R.; SUNDÉN, Daniel; BRADLEY, Jay. GlobalFestival: evaluating real world interaction on a spherical display. In: *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. Osaka, Japan: Association for Computing Machinery, 2015, pp. 1251–1261. UbiComp '15. ISBN 9781450335744. Available from DOI: 10.1145/2750858.2807518.

11. WILLIAMSON, Julie R.; SUNDÉN, Daniel; HAMILTON, Keith. The lay of the land: techniques for displaying discrete and continuous content on a spherical display. In: *Proceedings of the 5th ACM International Symposium on Pervasive Displays*. Oulu, Finland: Association for Computing Machinery, 2016, pp. 38–44. PerDis '16. ISBN 9781450343664. Available from DOI: 10.1145/2914920.2915005.

12. WILLIAMSON, Julie R.; WILLIAMSON, John; SUNDÉN, Daniel; BRADLEY, Jay. Multi-Player Gaming on Spherical Displays. In: *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. Seoul, Republic of Korea: Association for Computing Machinery, 2015, pp. 355–358. CHI EA '15. ISBN 9781450331463. Available from DOI: 10.1145/2702613.2725447.

13. WOBBROCK, Jacob O.; MORRIS, Meredith Ringel; WILSON, Andrew D. User-defined gestures for surface computing. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Boston, MA, USA: Association for Computing Machinery, 2009, pp. 1083–1092. CHI '09. ISBN 9781605582467. Available from DOI: 10.1145/1518701.1518866.

14. YIP, Ben; GOYETTE, Shea; MADDEN, Chris. Visualising internet traffic data with three-dimensional spherical display. In: *Proceedings of the 2005 Asia-Pacific Symposium on Information Visualisation - Volume 45*. Sydney, Australia: Australian Computer Society, Inc., 2005, pp. 153–158. APVis '05. ISBN 1920682279.

Chapter 6

Annexes

Appendix - Consent form

CONSENT TO PARTICIPATE IN A SCIENTIFIC EXPERIMENT

Study Title: Gesture Elicitation
Professor: Prof. Jean Vanderdonckt, UCLouvain
Experimenters: Quentin Lalou
Contact Email: jean.vanderdonckt@uclouvain.be
quentin.lalou@student.uclouvain.be

We thank you for contributing to scientific research by participating in this experiment. The experimenter will explain the purpose of the experiment and the questionnaires to be filled out. Please ask any questions you may have to the experimenter before starting the experiment. You may obtain a copy of this consent form and refer to it at any time.

By signing this document, I agree to take part in the experiment that has been explained to me. I have the right to stop it at any time by notifying the experimenter without any consequences. Once this consent is signed, an anonymous identifier will be assigned so that my name and surname will not appear anywhere other than on this form. I consent to the data collected in this experiment being processed for scientific purposes, strictly confidentially, and in accordance with the privacy regulations of UCLouvain and the General Data Protection Regulation (GDPR). Any photos or videos recorded during the experiment will not allow the participant to be identified, notably by avoiding the face or blurring it.

□ Please check this box if you agree to be potentially contacted later for other experiments conducted at UCLouvain or for an interview.
If applicable, email address: ....

Participant Declaration:
I, the undersigned ...., attest that the aforementioned experiment has been explained to me, that I have understood it, and that I agree to participate. I have read the above terms and accompanying forms, and I understand what the experiment will analyze.

Signature: Date:

Experimenter's Declaration:
I, the undersigned ...., confirm that I have explained the purpose of the experiment, its procedure, and its questionnaires, and, if applicable, the foreseeable risks of the proposed experiment to the participant.

Signature: Date:

Participant identifier : ....

LOUVAIN-LA-NEUVE | BRUXELLES | MONS | TOURNAI | CHARLEROI | NAMUR
Place des Doyens, 1 bte L2.01.02, 1348 Louvain-la-Neuve, Belgique
Tél. +32 (0)10 47 85 25 – jean.vanderdonckt@uclouvain.be – www.uclouvain.be/jean.vanderdonckt

Appendix - Survey

QUESTIONNAIRE TO FILL BEFORE THE EXPERIENCE

Here is a small questionnaire, feel free to ask any question to the experimenter if a question is not clear enough.

What number was assigned to you at the beginning of the experience ? ………..

What is your gender ? ......

How old are you ? .....

In which type of industry do you work ? ……................

In what type of role ? ....

On average, how many hours do you spend on a computer per week ? ....hrs

On average, how many hours do you spend on a device with a touch screen ? ....hrs

On a scale of 0 to 5, how frequently do you use a a computer ?

Not at all/never used one	0	1	2	3	4	5	Very often

On a scale of 0 to 5, how frequently do you use a flat touch screen (smartphone/tablet) ?

Not at all/never used one	0	1	2	3	4	5	Very often

On a scale of 0 to 5, how frequently do you use a spherical touch screen ?

Not at all/never used one	0	1	2	3	4	5	Very often

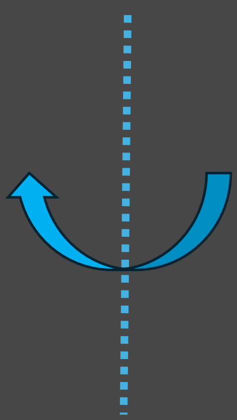
Appendix - Referents

Set of interactions on a spherical screen

Quentin Lalou
Jean Vanderdonckt

Navigation

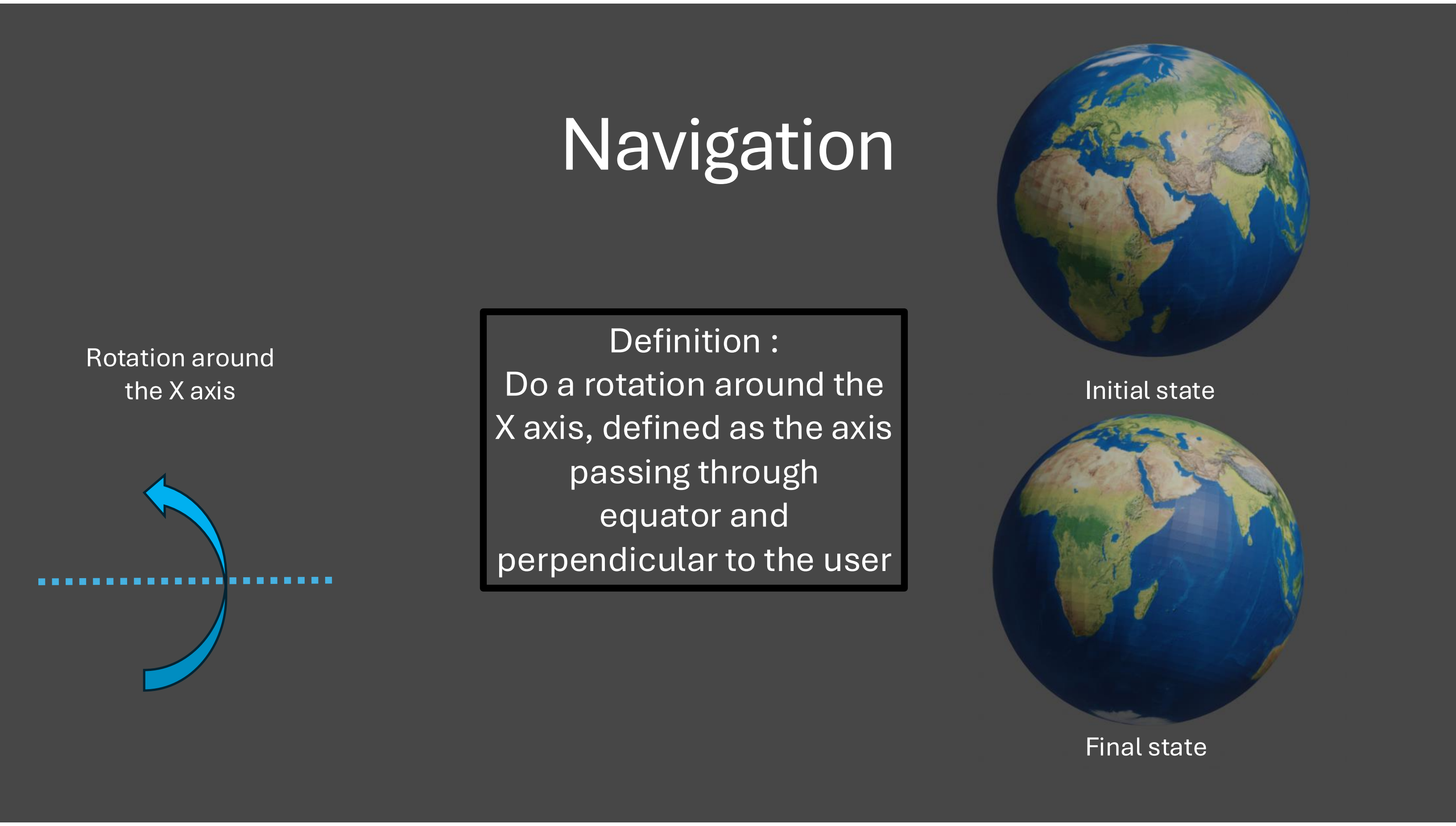
Rotation around the Z axis

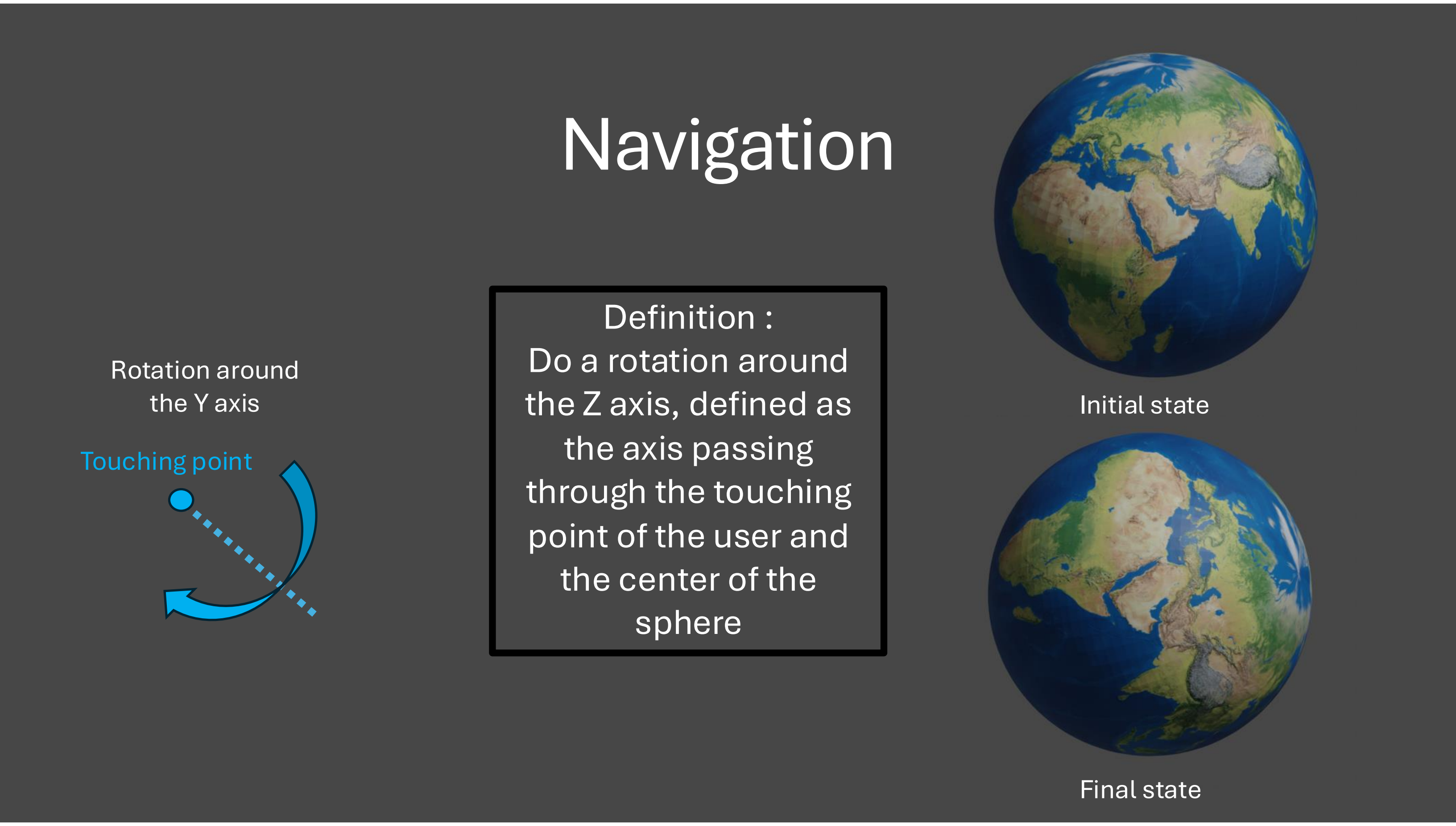


Definition :
Do a rotation around the Y axis, defined as the axis passing through the poles

Initial state

Final state


Navigation
Rotation around the X axis
Definition :
Do a rotation around the X axis, defined as the axis passing through equator and perpendicular to the user
Initial state
Final state


Navigation
Rotation around the Y axis
Touching point
Definition :
Do a rotation around the Z axis, defined as the axis passing through the touching point of the user and the center of the sphere
Initial state
Final state

Navigation

Zoom in

Definition :
Do a rotation around the Z axis, defined as the axis passing through the touching point of the user and the center of the sphere

Initial state

Final state

Navigation

Zoom out

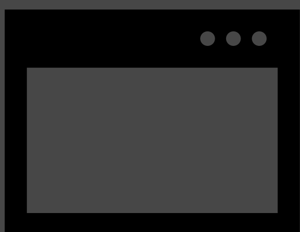
Definition :
Do a rotation around the Z axis, defined as the axis passing through the touching point of the user and the center of the sphere

Initial state

Final state

Interface

Open the menu



Definition :
Open a menu to process to further intaractions

Initial state

Final state

Change the type of map

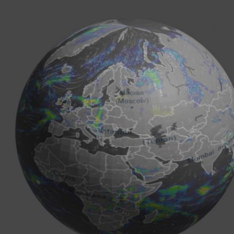
Change the type of map
4 types are shown here

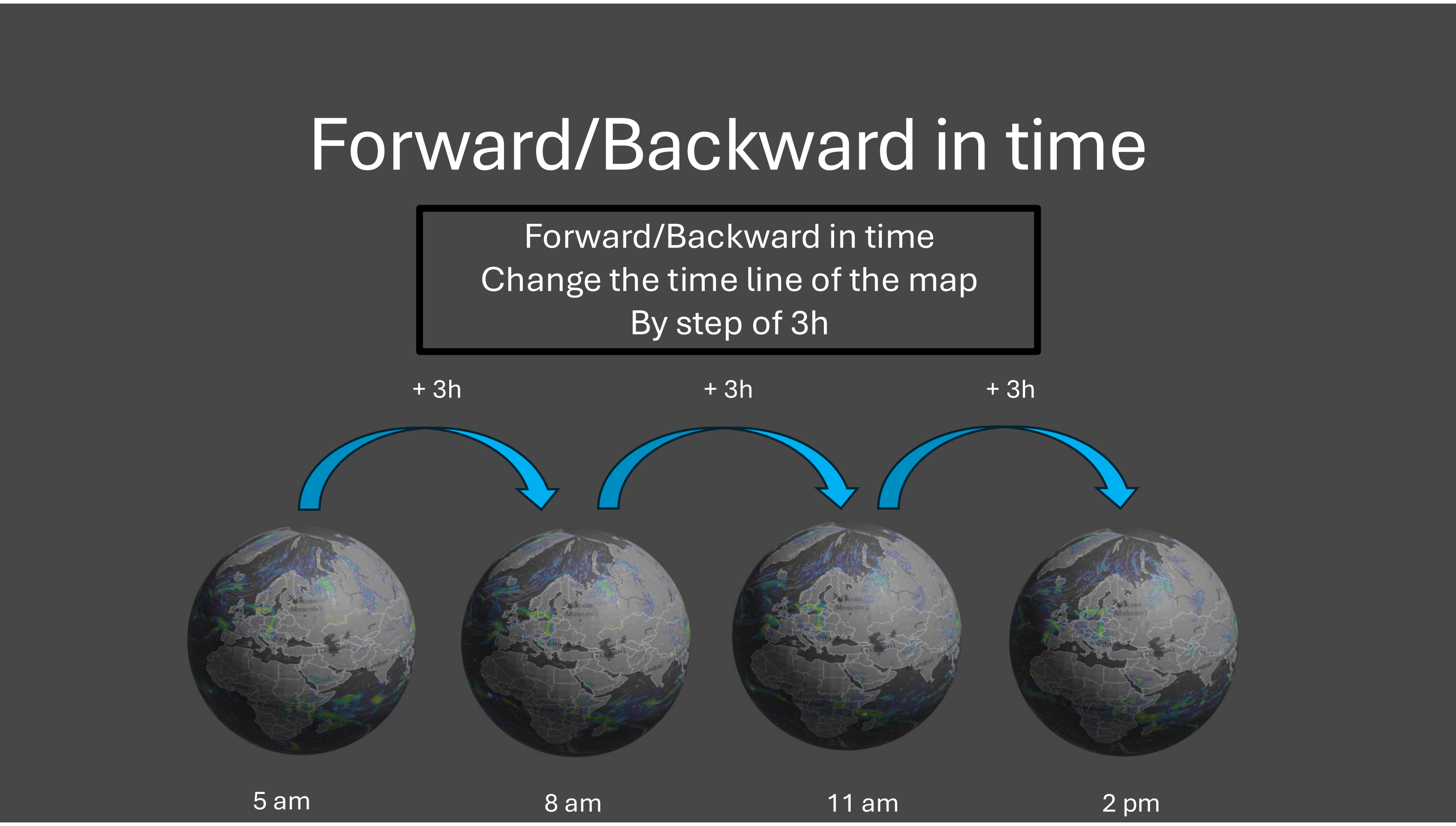
Topological map (T)

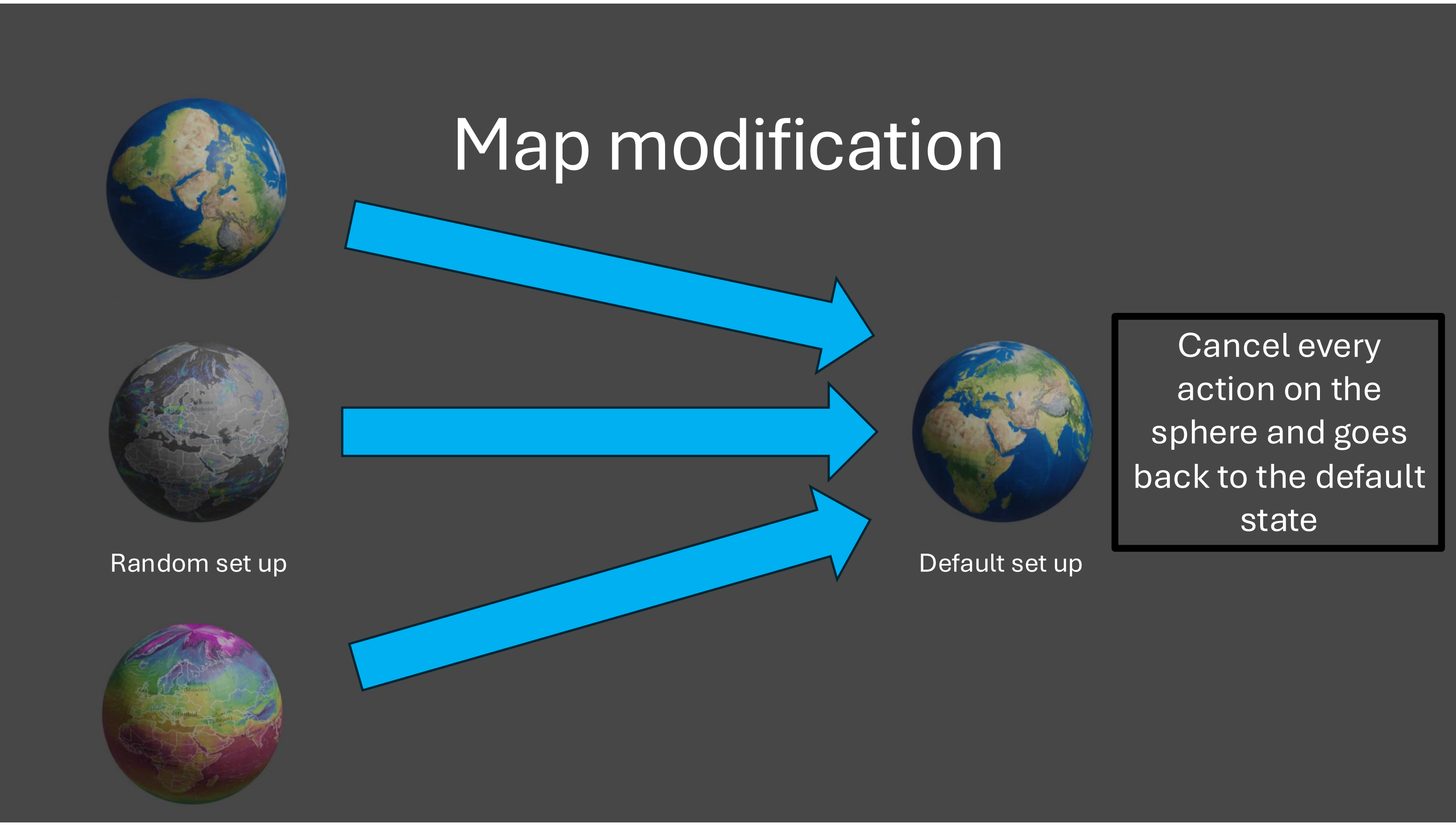
Political map (P)

Wind map (W)

Rain pattern map (R)

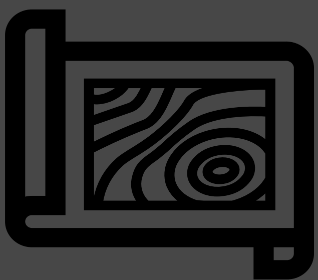



Forward/Backward in time
Forward/Backward in time
Change the time line of the map
By step of 3h
+ 3h
+ 3h
+ 3h
5 am
8 am
11 am
2 pm


Map modification
Random set up
Default set up
Cancel every action on the sphere and goes back to the default state

Area

Select an area



Definition :
Choose an area on the map, which will be colored

Initial state

Final state

Landmark & Path

Draw a simple path

Definition :
Draw a path between the 2 landmark

Initial state

Final state

Labdmark & Path

Initial state

Definition :
A path that has to pass
through every landmark

Final state

Landmark & Path

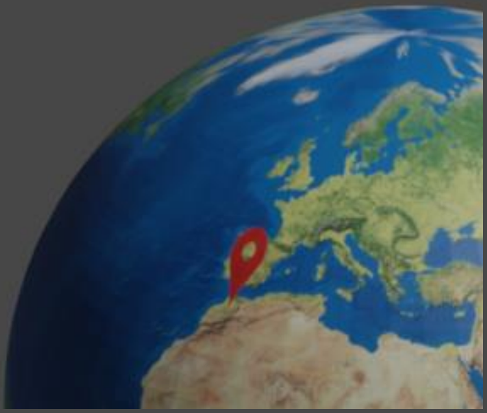
Initial state

Place a landmark

Definition :
A path that has to pass
through every landmark

Final state

Landmark & Path



Initial state

Definition :
Select a landmark, and
put it in highlighted

Final state

Landmark & Path

Definition :
Select a landmark, and
highlight it

Initial state

Final state

Landmark & Path

Definition :
Selected landmark is deleted

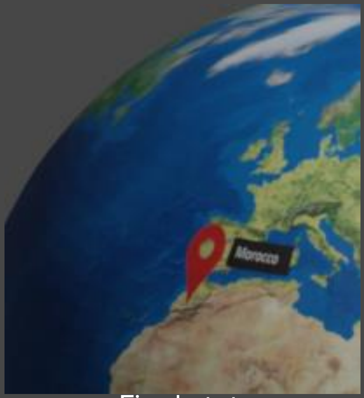
Initial state

Final state

Landmark & Name

Definition :
Gives a name to the selected landmark

Initial state



Final state

Landmark & Name

Initial state

Definition :
Shows a list of every landmark of the map

Final state

Landmark & Name

Initial state

Definition :
From the list of landmark, select a name on the list and go to the designated landmark

Final state

Coordinates

Initial state

Definition :
Highlight the selected meridian

Final state

Coordinates

Initial state

Definition :
Change the longitude of the meridian for a more accurate selection

Final state

Coordinates

Definition :
Delete the selected meridian

Initial state

Final state

Coordinates

Definition :
Highlight the selected parallel

Initial state

Final state

Coordinates

Definition :
Change the latitude of the parallel for a more accurate selection

Initial state

Final state

Coordinates

Definition :
Delete the selected parallel

Initial state

Final state

Appendix - Data

Data - Gesture

	Motion\Participant	2827	2341	7884	7287
1	Rotation Z	pan	pan	pan	pan
2	Rotation X	pan	pan	pan	pan
3	Rotation Y	pan	pan	pan	pan
4	Zoom in	pinch	pinch	pinch (2 hands)	pinch
5	Zoom out	pinch	pinch	pinch (2 hands)	pinch
6	Open the menu	press and hold	pinch (3 fingers)	press and hold	press and hold
7 (T,P,W,R)	Change the type of map	hold the pole	pan (draw)	interface use (menu)	triple tap
8	Forward/Backward in time	interface use (button)	triple tap	interface use (line)	interface use (line)
9	Reset	pan to the pole	hold the pole	5 fingers hold	hold the pole
10	Select an area	press and pan (2 fingers	pan (circular)	tap	pan (circular)
11	Draw a simple path	pan (draw)	pan (draw)	pan (draw)	pan (draw)
12	Draw a complex path	pan (draw)	pan (draw)	pan (draw)	pan (draw)
13	Place a landmark	press and hold	press and hold	tap	interface use (menu)
14	Select a landmark	tap	tap	tap	tap
15	Move a landmark	drag and drop	drag and drop	drag and drop	drag and drop
16	Delete a landmark	hold and swipe	double tap	interface use (button)	interface use (menu)
17	Name a landmark	keyboard use	keyboard use	keyboard use	keyboard use
18	List of landmarks	press and hold	specific tap	interface use (menu)	specific tap
19	Go to landmark	specific tap	specific tap	specific tap	specific tap
20	Select a meridian	pan (draw)	tap	pan (draw)	pan (draw)
21	Move a meridian	drag and drop	drag and drop	drag and drop	drag and drop
22	Delete a meridian	hold and swipe	double tap	interface use (button)	interface use (button)
23	Select a parallel	pan (draw)	tap	pan (draw)	pan (draw)
24	Move a parallel	drag and drop	drag and drop	drag and drop	drag and drop
25	Delete a parallel	hold and swipe	double tap	interface use (button)	interface use (button)

1399	6488	8578	6633	8528	3667	1833
pan	pan	interface use (button)	pan	pan	pan	pan (4 fingers)
pan	pan	interface use (button)	pan	pan	pan	pan (4 fingers)
pan	pan	interface use (button)	pan	pan	pan	pan (4 fingers)
pinch	pinch	pinch	pinch	pinch	pinch	pinch (2 hands)
pinch	pinch	pinch	pinch	pinch	pinch	pinch (2 hands)
triple tap the pole	triple tap	press and hold	specific tap	tap (2 fingers)	double tap	hold the pole
double tap	hold the pole	interface use (menu)	interface use (menu)	interface use (menu)	interface use (menu)	2 hands hold and swipe
interface use (line)	interface use (button)	clock motion	interface use (line)	double tap (particular)	interface use (line)	pan
hold the pole	interface use (button)	interface use (button)	hold the pole	hold the pole	hold the pole	hold the pole
press and hold	pinch	press and hold	press and hold	tap	press and hold	double tap
successive tap	pan (draw)	successive tap	pan (draw)	pan (draw)	pan (draw)	pan (draw)
successive tap	pan (draw)	successive tap	pan (draw)	pan (draw)	pan (draw)	pan (draw)
interface use (button)	interface use (button)	interface use (button)	press and hold	press and hold	double tap	press and hold
double tap	press and hold	tap	double tap	tap	press and hold	tap
press and hold	drag and drop	drag and drop	drag and drop	drag and drop	drag and drop	drag and drop
interface use (button)	interface use (button)	interface use (button)	interface use (button)	double tap	interface use (button)	hold and swipe
keyboard use	keyboard use	interface use (button)	keyboard use	keyboard use	keyboard use	keyboard use
press and hold	interface use (menu)	interface use (button)	specific tap	interface use (button)	double tap	press and hold
specific tap	specific tap	specific tap	specific tap	specific tap	specific tap	specific tap
interface use (button)	pan (draw)	interface use (button)	pan (draw)	pan (draw)	pan (draw)	pan (draw)
drag and drop	pan (draw)	drag and drop	drag and drop	drag and drop	drag and drop	drag and drop
interface use (button)	tap the pole	interface use (button)	press and hold	double tap	hold and swipe	hold the pole
interface use (button)	pan (draw)	interface use (button)	pan (draw)	pan (draw)	pan (draw)	pan (draw)
drag and drop	pan (draw)	drag and drop	drag and drop	drag and drop	drag and drop	drag and drop
interface use (button)	tap the pole	interface use (button)	press and hold	double tap	hold and swipe	hold the pole

9373	6731
pan	pan
pan	pan
pan	pan
pinch	pinch
pinch	pinch
press and hold	press and hold
interface use (menu)	interface use (menu)
interface use (line)	interface use (button)
interface use (menu)	hold the pole
border draw	tap
pan (draw)	pan (draw)
pan (draw)	pan (draw)
tap	tap
tap	tap
drag and drop	drag and drop
hold and swipe	interface use (button)
keyboard use	keyboard use
interface use (menu)	press and hold
specific tap	specific tap
pan (draw)	pan (draw)
drag and drop	drag and drop
hold and swipe	interface use (button)
pan (draw)	pan (draw)
drag and drop	drag and drop
hold and swipe	interface use (button)

Data - Thinking time

	Thinking time/Participant	2827	2341	7884	7287	1399	6488	8578	6633	8528	3667	1833	9373	6731	Average	Std
1	Rotation Z	2.3	1.06	9.01	2.36	4.54	2.11	53.9	6.19	7.87	2.97	8.46	5.85	2.47	8.391538	13.9313
2	Rotation X	3.94	0.54	3.95	1.2	1.5	1.87	25.5	4.06	7.76	7.7	7.82	5.79	1.83	5.650769	6.504906
3	Rotation Y	4.01	3.26	3.35	5.69	6.81	2.46	53.6	8.7	7.39	15.8	2.71	22.7	7.64	11.08615	14.02053
4	Zoom in	1.56	4.25	7.19	6.85	3.97	2.97	13.4	2.73	12.8	5.4	4.34	2.15	4.22	5.525385	3.742632
5	Zoom out	9.1	1.38	5.23	2.21	3.22	4.26	17.3	5.02	5.61	7.71	2.77	2.65	2.89	5.334615	4.222617
6	Open the menu	8.15	12	48.8	20.5	15	22.7	11.4	10.9	20.8	18.8	14.5	8.11	13.3	17.30462	10.59606
7 (T,P,W,R)	Change the type of map	24.06	25.4	16	0	3.99	3.42	19.3	41.4	15.8	23.3	11.7	35.2	16.7	18.17462	12.06698
8	Forward/Backward in time	25.8	32.9	43	26.8	20.5	20.2	38.9	20.3	20.3	23.6	5.66	23.8	14.6	24.33538	9.792954
9	Reset	33.98	24.7	13.6	25.6	12.7	7.73	31.4	19.5	14.4	37.5	44.9	42.7	8.6	24.40846	12.82616
10	Select an area	9.65	7.75	27.6	6.63	15.1	5.04	28.4	21.6	2.96	20.6	7.71	8.13	12.9	13.39	8.562071
11	Draw a simple path	4.2	5.49	13.5	10.3	10.2	4.13	40.1	23.5	9.26	4.33	4.87	51.6	6.18	14.43538	15.1038
12	Draw a complex path	4.78	11.3	8.66	5.23	17.3	5.34	44.1	13	6.1	7.03	5.7	18.1	6.73	11.79769	10.71259
13	Place a landmark	14.54	30.6	8.18	16.4	11.3	10.7	17	17.7	7.95	11.3	16.1	20.8	5.37	14.45692	6.599617
14	Select a landmark	1.21	3.6	6.92	3.54	3.67	2.46	15.2	1.79	4.29	2.62	6.86	5.13	4.87	4.781538	3.579434
15	Move a landmark	5.81	10.8	9.96	4.36	10.7	6.81	22.7	2.1	7.36	5.91	8.49	14.3	5.3	8.815385	5.265359
16	Delete a landmark	9.87	3.11	12.7	5.13	7.09	5.49	20.7	5.59	13.6	12	24.3	15.6	25.5	12.36	7.426851
17	Name a landmark	37.86	17	19.9	16.9	10	17.6	16.8	40.1	19.2	14.1	29.2	57.4	9.16	23.47846	13.9543
18	List of landmarks	23.79	9.74	25.5	13.8	36.5	2.94	1:09	55.6	32.7	14.5	22.7	21.6	30	22.26292	14.86573
19	Go to landmark	12.95	9.59	24.7	2.57	10.5	5.33	9.83	3.66	16.8	8.18	4.93	6.13	4.24	9.185385	6.172749
20	Select a meridian	4.32	17.95	18.1	5.2	29.7	25.3	33.6	9.49	22.4	10.3	6.42	27.4	9.91	16.93	10.03588
21	Move a meridian	4.03	4.11	7.16	7.03	6.47	10.1	6.15	11.9	8.97	2.92	13.5	14.1	6.39	7.91	3.589533
22	Delete a meridian	3.6	7.62	12.2	33.3	3.17	11.53	33.6	5.2	26.4	13.5	17.3	9.38	10.2	14.38462	10.44169
23	Select a parallel	6.81	2.87	36.9	7.93	7.39	9.84	11.6	6.98	6.24	16.5	4.82	11.7	4.67	10.32692	8.758593
24	Move a parallel	6.54	3.36	4.36	2.3	2.13	6.24	14.9	6.2	6.8	4.38	8.82	10.9	6.8	6.440769	3.550428
25	Delete a parallel	6.64	3.96	6.77	3.9	4.54	5.46	6.31	8.26	2.41	5.63	4.15	6.44	4.54	5.308462	1.574716

Data - Goodness of fit

	notes/Participant	2827	2341	7884	7287	1399	6488	8578	6633	8528	3667	1833	9373	6731	Average	Std
1	Rotation Z	7	10	8	10	10	10	10	10	10	9	10	10	10	9.538462	0.967418
2	Rotation X	7	10	8	10	9	10	9	10	10	9	10	10	10	9.384615	0.960769
3	Rotation Y	6	10	8	10	8	10	9	10	10	7	10	3	7	8.307692	2.136376
4	Zoom in	8	10	7	9	10	10	10	6	10	9	9	7	9	8.769231	1.363442
5	Zoom out	8	10	6	9	10	10	10	10	10	8	9	7	9	8.923077	1.320451
6	Open the menu	2	10	9	6	8	5	9	9	3	5	9	7	9	7	2.581989
7 (T,P,W,R)	Change the type of map	2	5	10	0	9	8	10	6	5	5	7	6	8	6.230769	2.948272
8	Forward/Backward in time	8	3	5	8	7	8	10	9	4	4	8	6	10	6.923077	2.325996
9	Reset	7	5	8	8	8	7	9	9	5	4	7	6	5	6.769231	1.640825
10	Select an area	2	8	9	8	8	10	9	8	10	7	10	4	6	7.615385	2.399252
11	Draw a simple path	8	9	7	10	6	10	7	8	10	8	10	6	8	8.230769	1.480644
12	Draw a complex path	6	9	7	10	1	10	7	9	10	7	7	6	8	7.461538	2.43637
13	Place a landmark	4	10	8	6	9	7	9	8	8	7	8	10	9	7.923077	1.656379
14	Select a landmark	10	10	9	8	10	10	10	8	10	9	10	10	10	9.538462	0.77625
15	Move a landmark	7	10	7	8	7	7	8	8	9	7	8	10	8	8	1.080123
16	Delete a landmark	3	10	6	8	7	8	9	8	4	5	6	8	4	6.615385	2.142369
17	Name a landmark	1	10	6	7	10	8	10	5	6	6	6	5	7	6.692308	2.496151
18	List of landmarks	5	6	7	7	9	8	10	3	3	6	4	6	5	6.076923	2.139374
19	Go to landmark	8	10	9	10	10	10	10	8	8	9	9	10	10	9.307692	0.85485
20	Select a meridian	4	5	7	5	6	9	9	6	7	8	7	5	6	6.461538	1.560736
21	Move a meridian	6	6	7	7	9	8	9	8	8	9	5	7	7	7.384615	1.26085
22	Delete a meridian	3	10	7	4	8	8	9	8	3	7	6	6	7	6.615385	2.18092
23	Select a parallel	1	10	4	7	7	8	10	8	7	6	7	5	8	6.769231	2.420532
24	Move a parallel	5	10	7	8	7	8	9	8	8	8	7	6	7	7.538462	1.265924
25	Delete a parallel	4	10	7	4	8	8	9	9	3	6	5	6	7	6.615385	2.18092

Resume :

This thesis presents an elicitation study conducted on a spherical touchscreen with 13 participants. The study focused on 25 referents and resulted in the collection of 325 unique gestures. Each of these gestures was classified and categorized to identify patterns and preferences in user interaction. The analysis revealed a clear dominance of one-finger gestures among the participants. Additionally, the study identified certain referents that exhibited exceptionally low agreement among participants, suggesting areas where intuitive gesture design is more challenging. Furthermore, the study highlighted the specific significance of the pole location on the spherical touchscreen, as it played a particular role for some of the participants oriented and executed their gestures. These findings contribute significantly to the understanding of user interaction with spherical touchscreens, providing valuable insights that can inform the design of more intuitive gestures for spherical display technologies.

Author :
Quentin Lalou

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management
Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve
Boulevard Emile Devreux 6, 6000 Charleroi, Belgique
Chaussée de Binche 151, 7000 Mons, Belgique
www.uclouvain.be/lsm