

MSc Interaction Technology Final Project

# Reintroducing Embodied Practices from Craft Work into Office Work through Spatial Computing

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#### Abstract

The work we do has become increasingly sedentary and the physical engagement once inherent to many professions has diminished, raising concerns about both physical and mental well-being. While society seems aware of this problem, current interventions primarily aim at mitigating inactivity rather than addressing the underlying issue: the design of work tools themselves. The design of modern computer-based tools prioritizes efficiency and cognitive ease at the expense of physical involvement, reinforcing a Cartesian separation between mind and body.

This research explores how spatial computing can (re)introduce embodied skills into office work to foster more physically engaged practices through a research-through-design methodology structured around three iterative design cycles. These iterations involve contextual inquiries with office workers and craftspeople, bodystorming co-design sessions, and prototype development and evaluation.

Findings from contextual inquiries revealed key differences between craft and office work, particularly in spatial use and tangible interaction with work artifacts. Observations informed multiple design concepts, three of which were further explored through bodystorming sessions that highlighted challenges in translating embodied interaction principles into office tools, including designing for skilled movements and balancing representation with direct sensorimotor engagement.

Based on these insights, this research culminated in the development of 'Spatial Git', a concept that visualizes and lets software developers see and organize code branches in physical space. Inspired by the spatial organization practices in craft work, the system reimagines digital workflows as physically distributed interactions rather than purely screen-based abstractions.

One of the most significant findings was that participants did not perceive the interactions with the system as (potentially) skilful, aligning with broader challenges in designing for embodied skill using mixed reality (MR). Skill development requires sensorimotor coupling, which is difficult to fully establish within the constraints of current MR technology.

Beyond the prototype, this research suggests a broader challenge in designing for embodied skill: skill cannot simply be imposed through predefined interactions but must emerge through sustained practice. This raises important questions about whether skilful digital interactions can be deliberately designed or if designers should instead focus on creating conditions that enable skill development over time.

This thesis contributes to the discourse on embodied interaction by exploring the possibilities of spatial computing to reintroduce physical engagement into office work. The findings highlight a need for methodological changes in order to design for embodied skills and call for a consideration of spatial computing as a significant subfield of MR research. "When the head and the hand are separate, it is the head that suffers", Sennett [56, p. 44]

"Or perhaps, in our current society, it is the hand that seems to suffer", Van Dijk (paraphrased, in response to this Sennett quote)

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# Chapter 1 Introduction

As many countries transitioned from an industrial economy to a service and knowledgebased economy, the prevalence of sedentary work increased dramatically. In the US, the amount of people that perform sedentary work has increased with 83% since 1950 [26], and in the Netherlands, 55% of workers now spend most of their workday sitting [19]. The work we do has become less and less physical, and increasingly cognitive, with the computer becoming the centre stage for many jobs [26].

While a decline in physically taxing and dangerous labour can be seen as a good development for worker health, the shift towards more sedentary work also has negative effects on worker's wellbeing. Prolonged inactivity is associated with physical and mental health problems such as cardiovascular disease, diabetes [4], reduced cognitive functioning and depression [54]. Beyond the effect on health, the decreasing physical engagement in our work also risks diminishing our ability to interact skillfully with the world around us.

Researchers and employers are well aware of the problem of sedentary behaviour. There have been many studies focusing on reducing sedentary behaviour at work [49]. Many studies employ behaviour change techniques such as nudging, gamification and increasing awareness [49]. Furthermore, in more and more offices, interventions such as standing desks and even under-desk treadmills are being adopted [17]. However, these developments seem more like band-aid solutions that only focus on making people move more, instead of introducing actual meaningful and skilful movement into the work practices. Current interventions seemed to be focused mainly on improving worker efficiency, rather than attempting to tackle the core cause of this reduced bodily involvement at work.

What seems to be closer to the core of the problem, is the design of the tools that are used to perform today's work. Interactions with the main tool that office employees use for work, the personal computer, has not meaningfully changed since the introduction of the GUI. The systems we use for our jobs today primarily engage our cognitive capacities. They are designed for minimal physical involvement and maximal efficiency. This bias toward disembodied, predominantly cognitive interaction is evident across many modern human-computer interfaces [13].

This disembodied stance in modern work tools, combined with the fact that many modern jobs do not deal with physical artifacts, can lead to jobs that are less satisfying and fail to trigger the sense of pride and accomplishment that arises from mastering physically challenging tasks [13]. It not only neglects the potential for enjoyment 'and pride that comes with acquiring and possessing motor skills [13, p. 12]', but also forms a threat to the (professional) identity of the one using the tool. The tools we use in-part shape our professional identities, and this focus on simplification could therefore also be seen as a breakdown of one's identity [53].

The prevailing cognitive design philosophy for the tools we use seems to be a result of the Cartesian way of thinking about skill, where we strictly separate cognition from action [13]. Where the Cartesian perspective on cognition and action seems to lead towards the creation of technological interfaces that focus more on cognition as disembodied processing of information (something that could be done without the rest of the body), and less on perceptual-motor skills [13], theories on embodied cognition step beyond that Cartesian split. Instead of separating cognition and action, embodied theories state that cognition and physical action are deeply intertwined [13]. These theories have proven to be interesting starting points for design, especially in the case of creating 'hybrid technologies', which include a mix of interactive and tangible artifacts [66].

In this study, I aim to explore how to reintroduce aspects of physical, craft-based occupations into office work by taking a critical look at the tools people use for work. To do this, I will to look at novel ways of interacting with computers. Several new interfaces, such as John Underkoffler's Minority Report-esque gesture-based interactions [62], or mixed reality (MR) devices, have been promising a 'revolution' that could shake up the way we use computers and do our work [7]. This is also one of the promises Apple made with the introduction of its own mixed reality device, the Vision Pro. At its introduction, Apple claimed to have ushered in the era of 'Spatial Computing', a term which will be further explored in Section 3.1.

But even these new interfaces seem to fall into the same 'simplifying' pitfalls as other modern interactive technologies. The technical capabilities of these new spatial computing devices allow for expansive 3D visualisations, interactions, and allow for the digital world to merge with real space. However, the latest generation of consumer spatial computing devices, such as the Apple Vision Pro, do very little to make use of the body and the space around it. For the Vision Pro, Apple chose to primarily rely on familiar 2D graphics, eye tracking, and minor hand gestures for interacting with the device. Most apps consist of 2D windows, that instead of being displayed on a computer screen, float in 3D space.

While spatial computing has the potential to change how we interact with technology, current implementations such the Apple Vision Pro do not seem to prioritize bodily involvement. This thesis challenges that by exploring how spatial computing can foster increased physical engagement in office work through the application of embodied interaction principles and by looking at craft work. This leads to the central research question:

How can we use spatial computing to (re)introduce embodied skills into office work to support more physically engaged practices?

#### 1.0.1 Methods

To address the research question, I employed a research-through-design (RtD) [77] approach structured around three iterations. RtD is a research method that integrates design practice as a means of generating knowledge. Unlike other forms of design research, which either study design as an external subject (research into design) or support design practice (research for design), RtD involves creating new designs as a mode of investigation [25].

As a foundation, I conducted background research in three key areas: embodied interaction, spatial computing, and craftsmanship. Embodied interaction provides a theoretical lens for understanding how physical skills shape the experience of work. Studying craftsmanship offered insights into the physical engagement and manual skills inherent in craft, providing an alternative perspective on the organization of tools and workspaces. Meanwhile, spatial computing will be explored as a concept to make these embodied interactions with work contents possible.

To establish the current research landscape, I reviewed related work in tangible and embodied interaction, focusing on tangible user interfaces, theories of rich user actions, and hybrid artefacts. This review was concluded by identifying research gaps.

The first iteration of the RtD process involved conducting contextual inquiries with both office workers and craftspeople. Insights from these observations informed the development of initial design concepts. In the second iteration, these concepts were refined through bodystorming sessions, generating further-developed concepts alongside new knowledge.

From these concepts, one was selected for further development into a prototype. This prototype served as both a design probe for evaluation and discussion with end users and as an aid for the communication of the design knowledge. This thesis concludes with a discussion of the findings and recommendations for future work.

#### 1.0.2 Disclaimer

This process and its activities that include human subjects was approved by the EEMCS faculty's Computer & Information Sciences ethics committee of the University of Twente under application number 240793.

At the time of this study, I am employed at one of the organisations included in this research (organisation A). While I do not expect a conflict of interests in the study, it is important to note that my relationship as a researcher to the subjects working at this organisation is different.

In this research I made use of Generative AI to help me improve some of my writing and with the development of the software for the prototype. In accordance to the University of Twente regulations at the time of starting this thesis, I have included a section on the usage of AI in this study in the appendix.

# Chapter 2 Background

In this section, I will explore the evolution of (office) work and its relationship with modern technology and craftsmanship. First, I will provide a brief historical overview of modern office work. Following that, I will delve into the concept of craftsmanship where I will examine how it has been affected by the pressures of modern productivity standards and technology. Additionally, I will introduce the theory of embodied skills, focusing on how physical interaction with tools shapes our ability to perform tasks skillfully. Finally, I will discuss the emergence of spatial computing, analysing how it has the potential for changing the way we interact with digital and physical spaces.

#### 2.0.1 A (short) history of modern office work

Before the 17th century, the vast majority of people worked from the home domain [9]. The first signs of the modern office can be traced back to the early 17th century, when industrialisation and large companies such as East India Company started to establish a complex bureaucracy to manage its far-reaching trading operations. This laid the ground-work for the development of offices as we know them today [39].

In the 19th and early 20th centuries, inventions like the telegraph and the telephone revolutionized how work was done and where offices were located. These technologies allowed offices to be separate from factories, leading to a division between white-collar and blue-collar workers [9]. Although these innovations hinted at the possibility of distributed workforces, in practice, American offices grew more centralized [9]. In the period between 1960 and 1980, the amount of people working from home in the US declined from 4.7 million in 1960 to 2.2 million in 1980 [58].

Management theories have played a crucial role in shaping the modern office. Modernist thinkers such as William Henry Leffingwell and Frederick Taylor pictured the office as a factory [9, 43]. They saw work as a series of tasks that could be 'rationalized, standardized and scientifically calculated into an efficient production regime' [9]. Where the office worker first had responsibility and a highly esteemed status, through 'Taylorism' office jobs were simplified and reduced to a series of repetitive tasks that could be done by lower-educated workers [43]. The design of office spaces was evolving to prioritize the optimization of worker efficiency. For example, high-backed office chairs that provided a degree of privacy were standard at the time were replaced by furniture that gave supervisors more ability to check on worker performance [43]. This ever-growing focus on efficiency, together with several societal developments such as deregulation and privatisation, led to a low point in office wellbeing. Modern offices were making people sick due to bad air quality and a lack of natural light [43].

Starting in the 1970s, through activism of office worker unions in the Netherlands and Scandinavia, the first efforts to re-humanize the office developed [43]. One example of such an office are the Centraal Beheer offices in Apeldoorn, designed by Herman Hertzberger in 1973. It achieved this by designing a complex, interconnected interior made up of several "work islands." Each island accommodated 16 employees who were encouraged to personalize the space to their liking, including bringing in their own plants and pets.

Today, digital advancements seem to be signalling the end of the traditional office. With online connectivity, many people can work from home [9]. This is reflected in statistics: the amount of people working from home has been rising since 1980 [58]. The COVID-19 pandemic saw a big rise in people working from home, due to precautions and restrictions. In 2021, the midst of the pandemic, the estimate is that 17.9% of the US workforce worked from home [58].

After the pandemic, things did not immediately return the situation before the pandemic. Many employees across different companies experienced the advantages of working from home and refused to go back to normal, causing a conflict between employers and employees. Such has been the case for Apple [23], where over 7000 employees united against a (full time) return to the office.

Furthermore, open-plan offices, a popular type of office layout that has most employees together in an open space, have been subject of widespread criticism among many of the people working in them [8, 27, 43]. Research suggests that when employees are moved to open-plan offices, they often do not interact with each other as much as they do in traditional office setups [27], are less productive [8], and are sick more often [27]. Reasons that are mentioned for this are the fact that people are distracted more easily and that certain open spaces can negatively impact our memory [8]. This last statement is especially relevant in the case of 'hotdesking', a type of office practice where no employee has a fixed desk [8].

However, there is also evidence that working near other people in an office has benefits. Anthropological research suggests that the office environment plays a crucial role in effective leadership and teamwork [43]. Being together in-person allows for better communication and collaboration [9]. This is also what Apple's SVP of retail and people operations said in response to the backlash against the return to the office [23]. It is interesting to see such a difference in between the theory of working together, and the actual practical experiences of people. One would think that we, as social beings, would prefer working together with other humans instead of isolating ourselves in closed spaces. But I wonder if this perhaps has to do with the fact that the mode of work is incompatible with inherent human behaviour. If we need to isolate ourselves to force a mode of hyper-focused behaviour to deliver our best work [8], perhaps the type of work, or the way the work is executed, does not align with our needs as humans.

#### 2.0.2 Craftsmanship(-as-a-practice)

A growing number of researchers are turning their attention to work as a form of craft or skilful performance [75]. This renewed interest in craftsmanship appears to be a response to the modern methods of work introduced alongside industrial assembly line production [75]. Assembly line work is linked to a methodology shift from doing things a good or correct way, to doing something as efficiently as possible [75].

According to Sennett [56, p. 9], craftsmanship refers to an individual's desire 'to do a job well for its own sake'. The concept is not limited to skilled manual labour, but can be seen in almost all domains, even in activities we would not classify as work, such as parenthood [56]. Lucas and Spencer [38] propose that it is most helpful to focus on craftsmanship as a certain attitude, rather than being the outcome of formal training and mastery. To highlight the facts that craftsmanship is more than just a job involving craft, and that it is an attitude that can appear in many types of work, I propose to use the term *craftsmanship-as-a-practice*.

Lucas and Spencer [38] name several positive traits that craftspeople seem to contain. Among these are attentiveness, precision, ambitious goal setting, responsibility, and a reflective attitude. Furthermore, the authors state that 'developing individuals with *craftsmanlike* dispositions can provide people with a sense of orientation that engages them with their work' [38, p. 6]. Sennett [56] suggests that craftsmanship offers two emotional rewards; 'people become anchored in tangible reality, and they can take pride in their work' [56, p.21].

Lucas and Spencer [38] state that while craftsmanship seems to be becoming a more popular subject in research, it seems like the presence of craftsmanship in society and the workforce is in decline. There are many factors and developments that put pressure on craftsmanship, such as a general decline in tool use within society, developments in education, and changes in the workforce such as flexible working [38].

But perhaps the most important factor that might play a role in the decline of craftsmanship is technological development. The integration of digital technologies into the workplace has fundamentally transformed how work is quantified and assessed. Modern organizations increasingly leverage information and communication technologies to measure various work processes, reflecting a shift from qualitative to quantitative evaluations [75]. By breaking tasks down into measurable units, organizations can track performance, efficiency, and productivity with greater accuracy. This emphasis on quantification could lead to the standardization of work processes at the expense of the subjective and experiential knowledge that craftsmen develop over time [75].

Many of the technologies in use in the workforce today reinforce the Cartesian split between the thinking mind and the working body, creating a framework that suggests work, along with the thoughts and emotions of workers, can be measured for efficiency [75] (more on this in section 2.0.3). Meanwhile, Sennett [56] argues that craftsmanship can still occur with digital tools, considering for example coding as a form of craft. Nonetheless, he warns that technological developments may cause craftsmen to become passive users of technology, leading to a disconnect from its potential in fostering new skills.

#### The studio

I would argue that both having *actual* control over means of labour (to improve how the work is done) and *feelings* of control and authority over means (to have increased psychological ownership [52]) could be important components to craftsmanship-as-a-practice. With this, I want to highlight the role of the workplace of a craftsman: the workshop or *studio*.

Werdhaningsih [74], Fallman [20] note the double meaning of the word studio. It can both mean the physical workspace of a craftsman, and a practice or collaborative way of working: a work culture. Fallman [20] argues that one influences the other - that the physical dimensions and arrangements of a studio space such as the physical design of the building and furniture influences the studio practice. A successful studio (for both meanings of the word), according to Fallman [20], finds a balance between promoting creative and collaborative activities in shared spaces, and supporting individual work in personal spaces.

Another typical aspect of a successful studio, is the fact that they are often full of 'concrete' elements, such as photo's, notes, sketches. While not every item might have a direct connection to specific projects, collectively they contribute to an idea-rich environment that fuels creativity [20, 71]. This aligns with a 2010 study that has shown a positive relationship between people's perceived control over their work environment, and their ability to focus [18]. Elsbach and Bechky [18] also mention that allowing personal office decor and having task-relevant objects (such as tools) on display are important for the formation of a professional identity.

Although literature on this is limited, I hypothesize that the act of organizing and shaping one's own work environment or studio may foster a sense of ownership and be integral to craftsmanship as a practice. This makes it a compelling subject for further research.

#### 2.0.3 Embodied Skills

Embodied theories arose as a direct response to the persistent influence of Cartesian dualism - the separation of mind and body - in the fields of (phenomenological) philosophy, cognitive science, and ecological psychology [66, 65]. The concept of embodiment has gradually become more significant in the field of interaction design over the last two decades [13]. Paul Dourish combined this research into different embodied theories from a phenomenological point of view into his book 'Where the Action is: The Foundations of Embodied Interaction' [14], forming the foundation for the field of embodied interaction design.

Central to the concept of embodiment is a rejection of Cartesian dualism or the mindbody split. This split refers to, in part, the way we look at cognition and action. The orthodox, Cartesian, perspective frames the body as a simple executor of the mind [13]. This split between cognition and body is deeply embedded in modern thought, and seems to influence the way we shape our society [31]. It leads to the prevailing view on interaction design that the actions taken by a user in interaction should be made as easy as possible [13]. However, making an interface operationally simple shifts the burden of using the system from physical action to almost exclusively cognitive processes [13].

Embodied theories instead argue that the body is not just an instrument that our brain uses, but that it is essential for our interactions with and understanding of the world [13]. This perspective challenges the traditional view of the mind as the source of all human activity, instead emphasizing the role of our physical experiences and social interactions in shaping our understanding.

#### Developing embodied skills

Humans are skilful beings capable of skilful action. In skilful action, a human is able to act without a detached cognitive 'preparation' phase. The action and perception happen in parallel and become coupled [67].

In his 2001 book on the anthropology of skill, Ingold [31] describes an experiment in which participants tried making a completely unfamiliar and complicated knot. They were given detailed verbal instructions and diagrams, but still found the task extremely challenging. The main difficulty was translating the instructions, both written and visual, into physical actions [31]. This experiment suggests that knotting, a common practice across human societies, cannot be reduced to a simple set of instructions or a program. This means that the skill of knotting cannot be learned by simply memorizing rules or studying diagrams: separate cognitive action.

While skills are deeply ingrained in human experience, this phenomenon seems to be puzzling for philosophy [60]. In their 2011 paper, Sutton et al. [60] seek to explain the tension between the seemingly automatic nature of skilled movements and the involvement of some form of intelligence or mindfulness in these actions by combining phenomenological

philosophy with psychological theories.

Sutton et al. [60, p. 78] argue against the view of some phenomenologists such as Dreyfus that any 'mindedness' (cognitive action) goes against embodied coping. They propose that while these actions may not involve explicit deliberation or reflection, they are not entirely mindless either. Instead, they suggest that a form of dynamic, embodied intelligence is at play, which allows for flexible and adaptive responses to the environment. This intelligence is not about explicit planning or rule following but rather a more intuitive and context-sensitive understanding of the situation [60].

Following this perspective, skill can be understood as the ability to act intelligently within a given environment, without a separate cognitive preparation phase [67]. People in skilled movement domains, such as athletes, recognise that self-conscious thought can disrupt well-practised actions. However, they also recognize the need for adaptability in dynamic situations [60]. In skilful action, there is no separation between perception and action; rather, they occur simultaneously and become intertwined. This combination of perception and action is called a sensorimotor coupling or loop [67].

Sensorimotor couplings describe the way in which the living body constantly adapts and coordinates its movements in reaction to external changes or disturbances [66]. Coordinated movement is achieved through the connection between sensory input and motor output. This loop, influenced by scaffolding and the opportunities for action and perception [31], results in the formation of behavioural patterns that are suitable for a particular context. These sensorimotor couplings create a sense of 'attunement' or connection with the world, which is constantly adjusted as the relationship between the body and the environment changes. The development of these sensorimotor couplings can be viewed as the acquisition of skill [66].

If you look through the lens of embodied cognition, you can see embodied skills present in many domains. Take for example the swing of an experienced tennis player. When aiming to hit a ball to the left-back of the field, the tennis player does not consciously think about how much to turn their wrist, when to hit the ball, or how to follow through their swing. Instead, the tennis player just hits the ball where they want it to go. It is not a pre-programmed action the tennis player is performing, because the speed, bounce, and angle of the ball is dynamic. The tennis player knows - in the moment - how to act in order to achieve their goals.

#### The role of tools

According to Heidegger's phenomenological ontology, tools (or any other entities), have two ways of showing up to us in the world. Heidegger calls an entity *present-at-hand (an imperfect translation of the original german 'vorhanden')* when we encounter the entity in distant, analytical way. In this mode the entity is an object of attention. This happens, for example, when something occurs to use for the first time. In the Cartesian way of viewing the world, the present-at-hand mode of being is dominant. Objects are seen as existing independently of our experience, and their essence is defined by their properties, such as size, shape, and motion. The mind, through reason and observation, can accurately understand and represent these objects [53].

The other way an entity can show up, according to Heidegger, is *ready-to-hand ('zuhan-den'*). In this mode, an entity shows up 'in fluent use as a means for practice' [53]. How the entity shows up depends on its use, its relation to other objects, and on the user. This challenges the Cartesian worldview on objects. Objects that are ready-to-hand are not just things with properties, but are defined by their use and functionality within our practical activities, without the need for separate reflection [53].

In his 2001 work, Ingold [31] describes the practices of bag weaving (bilum) among the indigenous Telefol people of New Guinea. In order to make the bags, the only tools the maker uses is a mesh gauge made from a strip of leaf, and a needle made out of bone [31]. The craftsperson doesn't merely 'use' the tools; they become one with them, with their hands moving in harmony with the rhythm of weaving. The tools themselves are not just passive objects but extensions of the craftsperson's body, their forms and functions shaped by generations of embodied knowledge and practice. This intimate relationship between the craftsman, the tool, and the task is a good example of embodied skill. The tool becomes part of the sensorimotor loop [66]. To novices, encountering the tools used to create bilum bags would show up as present-at-hand. For a craftsperson, these same tools show up as ready-at-hand.

Not every tool affords the same type of action. A tool has certain affordances that depend on the background, skills and environment of the actor, that mediate how an actor perceives and uses the tool. In Heideggerian terms: an object has an *in-order-to* [53]. These affordances are not set in stone and not determined by designers - they depend on things like the situation in which the tool is found, and the person that perceives the tool: the lifeworld [66]. The tools used by the Telefol to create the bilum bags have different affordances to the skilled craftsperson than to a novice. While it is not possible for a designer to 'design' affordances, they can try to design technology to support the formation of couplings and meaning [66].

So what makes an object a tool suitable for skilled use? Ingold [31] creates the distinction between technique (skill) and technology (generalized knowledge), and likewise between tools and machines. Machines, in contrast to tools, operate independently of human agency and reduce the user's role to inputting power or force. A machine is mechanically determined - there is no room for skilled manipulation. According to Ingold, as we transition from *tools* to *machines*, we lose the direct, skilful interaction between human and object [31].

Next to being important for skilful actions, there is an element of pride related to skillfully using tools [13]. A risk with many modern (information) technology tools, is that they lack the qualities for users to express their identities - threatening the lifeworlds of their users [53].

# Chapter 3 Related work and technology

In this section, I introduce the concept of spatial computing alongside related work in tangible and embodied interaction. I focus on key areas such as tangible user interfaces (TUIs), rich user actions, and hybrid artifacts, which together provide a foundation for exploring how embodied interaction principles can inform the design of interactive systems.

While spatial computing brings its own unique opportunities and challenges, I consider insights from these related domains to be highly relevant. Additionally, I examine current research on promoting more active forms of office work, as well as recent developments in spatial computing technologies for workplace settings.

# 3.1 Spatial computing

In the introduction of this thesis, I referred to the term *spatial computing*. It is primarily a marketing term that consumer technology giant Apple uses for the category that their head-mounted mixed reality (MR) system Vision Pro falls in [2]. Spatial computing is a term that is not ubiquitous in scientific literature to denote mixed reality user interfaces. The term has previously been in use within the Geological scientific community to denote computer interfaces that refer to physical spaces and places, made possible by technologies such as GPS and remote sensing [76].

More relevant to the context of human-computer interaction, the Spatial User Interaction conference publishes research focuses on the design challenges of creating user interfaces that integrate digital content into our three-dimensional world [1]. In addition, there has been a call for the creation of a special interest group (SIG) focused on spatial computing in the CHI conference [76].

While the Apple's Vision Pro hardware can be classified as a mixed reality headset, the term spatial computing seems to suggest an emphasis on the *locatedness* and *spatiality* of the experience. While it is debatable if this device currently enables this, the term spatial computing gives us an interesting perspective on how mixed reality can enable a new way

of interacting with computers beyond just new input or display methods. It describes how computing can be integrated differently into our three-dimensional *lifeworld*. Therefore, I will continue using this term to describe the design that is explored in this study.

What will follow in the rest of this section is a short breakdown of the term mixed/ augmented reality according to Milgram's 1994 taxonomy, and some of the challenges of designing for this with a focus on skilled interactions.

#### 3.1.1 Mixed Reality

Mixed- (MR) or augmented reality (AR) can be defined as the digital augmentation or superimposition of information over a user's view of the real world [50]. Augmented reality has the ability to modify our perceptory space [30]. Hugues et al. [30] define that 'globally, the aim of AR is to enable a person to carry out sensory-motor and cognitive activities in a new space by associating the real environment and a virtual environment.' This merging of the physical and digital realms opens up exciting possibilities for enhancing, supporting or utilizing our embodied skills.

One of the earliest taxonomies of mixed reality was created by Milgram and Kishino [42]. They defined everything that falls between a fully real and fully virtual environment as mixed reality. On the resulting 'virtuality continuum' augmented reality and virtual reality are placed at different intervals. This continuum can be seen in Figure 3.1. While there are different distinctions to be made in classifying this spectrum, this is not immediately relevant in the context of this research.



Figure 3.1: Virtuality Continuum [42, p. 3]

#### 3.1.2 Challenges

There are several technical obstacles that challenge the widespread adoption mixed reality devices, such as display technologies and battery life Van Krevelen and Poelman [68]. Next to this, Djajadiningrat et al. [13] argue that despite the potential of MR platforms to offer a truly embodied experience, current systems fail to achieve this due to shortcomings of how medium is used.

Their first argument is that many designers do not incorporate the complexities of motor skills and manual dexterity into design for MR, relying instead only on simplistic methods like collision detection and basic "grabbing" interactions [13].

Secondly, they state that the environments made in MR will never achieve a perfect representation of the real world. Instead, MR environments have only a selective and superficial similarity to the real world. This means that our real-world abilities cannot be seamlessly transferred into the virtual environment [13]. However, this can also be used as a strength. For example, it can help visualize things that are not usually visible because the phenomenon might be obstructed, from the past, from the future [30] or simply impossible [30, 59].

Finally, the authors argue that gesture-based systems, on which many of the interactions with MR devices rely, often fail to establish a meaningful connection between the 'physicality of the object and skilled actions' [13, p. 8-9]. The gestures used are often superficial and need to be learned like a language.

## 3.2 Tangible and Embodied Interaction

#### 3.2.1 Tangible User Interfaces

One of the foundational concepts in the field of tangible and embodied interaction (TEI) is the concept of Tangible User Interfaces (TUIs) [34]. The core concept of TUIs is to give physical forms to digital information. These physical forms act both as representations of the digital information and as the controls to manipulate it. The interface between people and digital information requires two key components: input and output, or control and representation. Controls enable users to manipulate the information, while representations are perceived with the human senses [33]. By doing this, TUIs enable users to directly interact with digital information using their hands and perceive it through their senses due to its physical embodiment.

While tangible representations in TUIs offer a direct link to digital information, they have limitations in dynamically changing their physical properties. Unlike pixels on a screen, physical objects are difficult to alter in real-time. To overcome this, TUIs incorporate 'malleable' representations like video projections and sounds alongside the tangible elements. These intangible representations enhance the dynamic expression of digital information and computation [33].

One example of such a TUI is Urp, a system for urban planning [64] which uses projection mapping and physical building models to simulate various architectural challenges such as pedestrian-level wind flow, shadows and reflections. By moving around the physical building models you influence the simulation, which is visualized by the projections.

The concept of TUIs has been followed up with a lot of related work from the field, much ending up in the TEI (Tangible and Embedded Interaction) conference. Ishii already names several promising applications for this concept in his 2008 [33] paper, such as interactive surfaces, tangible telepresence, and augmented everyday objects.



Figure 3.2: Urp visualizing wind flow between buildings [63]

#### 3.2.2 (Rich) User Actions

In response to the concept of TUIs, several authors emphasized that the concept of manipulating computer content through physical objects does not sufficiently challenge how technology is designed [35]. Jensen et al. [35] emphasize the importance a focus on user actions, instead of the representation of information. The authors argue that current interaction styles ignore the possibly beautiful physical skills humans are capable of.

Such skills are still present in some occupations. In their 2005 paper, Jensen et al. [35] observed the practices of workers in an industrial context, specifically workers in a brewery. The authors describe the skilful work of an operator doing routine testing of a bottle-filling machine, performing an almost dance-like choreography.

This focus on actions requires a new approach to the process of designing. To transform the insights from the observations to actionable design insights, the authors describe several novel techniques and methods. One of these is taking a new perspective to ethnographic research, combining the wide angle view on human practices with a macro focus on the specific actions that make up this human activity. The authors also describe taking inspiration from historical interfaces as a starting point for designing new tools [35].

Frens [21] describes the design and evaluation of a camera that is designed with a focus on rich user actions. In order to design this camera, the author created five prototypes that were based on five artificially chosen themes, such as 'a camera that fits the body' and 'a camera that has no labels on its controls'. The final prototype was based on the latter theme, with the author arguing that this version contained the most expressive relations between form, interaction, and function.

Figure 3.3 displays several functions of the rich UI camera, such as turning it on by removing the lenscap (a), saving an image by moving the screen towards the memory card (g), and moving an image toward the lens to discard it (h) [22].

Frens [21] concludes with defining three main aspects of rich interaction, first of which is 'to integrate form, interaction, and function' [21, p. 212]. Furthermore, he states that



Figure 3.3: Prototype of the rich UI camera, displaying several functions [22, p. 3]

rich interaction taps human skills through expressive form, not through abstraction. Finally, Frens [21] states that aesthetic interaction is formed by this combination of the former two aspects.

#### 3.2.3 Hybrid artefacts

The term "physical-digital hybrids," or simply "hybrids", builds further on insights from various research fields such as TUIs, ubiquitous computing, and augmented reality [67] [66]. Where TUIs acknowledge the extension of cognition into the external world through tools and artifacts, they keep up a fundamental division between content and the physical realization [66]. Hybrids challenge the Cartesian separation between the physical and digital by incorporating digital components into physical forms. This combination can lead to new and unconventional artifacts, partly because they challenge that distinction between the 'inner' human user and the 'outer' social and physical environment. The 'design for embodied being-in-the-world' framework can help designers understand how to create hybrids that bridge this gap and create a more integrated experience for users [66].

One example of such a hybrid is MyDayLight, a system designed to support structuring daily activities for a person with Autism Spectrum Disorder [67]. This system consists of a lights system that the user can program to highlight tasks based on a schedule. For

example, the user can schedule to do the dishes every day at 11PM on a tablet. When it is time to do the dishes, a tangible highlight lights up in the kitchen, drawing attention to this task. The user can place these highlights anywhere.

There are several key details in the way this system is designed, show this aforementioned breakdown of splits. Firstly, instead of relying on information messages that need to be interpreted by the user, MyDayLight (Figure 3.4 relies on light cues that help the user guide their attention to the appropriate action. Furthermore, the lights itself convey very little information. They only highlight the already meaningful things in the living space of the user, seamlessly embedding into the lifeworld [67].



Figure 3.4: Prototype of MyDayLight [67]

# 3.3 Active office work

Reducing sedentary behaviour in office work and improving worker wellbeing has been a topic among several recent research papers. In this section, I will highlight several of the interventions using several literature reviews on this topic [49, 11]. These reviews identify three main categories of interventions: physical changes in workplace design and environment, changes in organisation and policy of work, and information provision. Many studies combine two or more of these categories into a multi-component intervention.

Among the first category, physical changes in workplace design and environment, we can place interventions such as sit-stand desks. Shrestha et al. [57] identified that using these desks can reduce sitting time by on average 100 minutes per workday in the short term and on average by 57 minutes per day. This seems to suggest that while sit-stand desks have a positive effect on active behaviour, this effect seems to decrease with time. Other physical interventions such as under-desk treadmills or pedal machines had unclear effects on sitting time.

A different category of interventions are policies to change the organisation of work.

This could mean a policy to have more meetings as 'walking meetings' [57, 12], having purposely short breaks, or having standing-only meeting rooms [57]. The effect of such interventions varies. Shrestha et al. [57] found no significant effects on sitting time among the papers analysed, while having short breaks instead of longer breaks did decrease sedentary behaviour.

The final category of interventions are centred around providing information or counselling on the topic. Brombacher [6] presents such a system, which visualises wellbeing data through tangible, ambient displays embedded in the office environment. This category also includes several studies that use computer prompts reminding the worker to stand up. These interventions seemed to result in no significant change in sitting time on the short term, but did have more significant effects in the longer term [57].

In their 2024 literature review, Parés-Salomón et al. [49] focused on identifying the use of digital technologies across interventions to reduce sedentary behaviour among office workers. Among the 19 papers included in the review, the majority (16) included multi-component interventions (meaning a digital element in combination with the previously mentioned categories). In 18 of the studies, digital media were used to provide information. This was done in several ways: e-booklets, digital newsletters, a website, online sessions, video, toolkit, a smartwatch, and gamification. Other uses for digital technologies were automated tailored feedback, scheduled prompts to take a break, passive data collection, and mediated organisational support.

### 3.4 Spatial computing in the workplace

Through a systematic review of literature, Vasarainen et al. [69] identified three main application areas of MR in working life across 26 eligible papers from a sample of 485: design, remote collaboration, and training. These are the same three themes that can be found on Meta's 'Meta for Work' marketing page [41], with the Meta page also including 'building community'.

#### 3.4.1 For design

A large part of the design-related research papers that were identified by Vasarainen et al. [69] focused on urban planning, while another large category of papers were focused on the automation, engineering and construction sector. A recurring theme in the papers that were found was collaborative design.

In a more focused literature review on specific applications of MR in design practice, Giunta et al. [24] identified 21 papers, categorizing them based on the stage of the design process where MR was utilized. These stages were based on a model created by Pahl et al. [48]. The authors found MR applications for each of the design stages Pahl conceptualized, except for the 'task' stage. This stage of the design process is concerned with planning and clarifying the design task [48]. Most of the applications that were found focused on the concept, preliminary (first iteration of design based on concept) and definitive layout (more detailed and reflective stage) phases of the design process.

#### 3.4.2 For remote collaboration

Vasarainen et al. [69] identified six studies addressing remote collaboration in mixed reality, with three specifically examining remote work meetings. The topic of collaborative mixed reality experiences is widely studied in its own right.

Remote collaboration is also something that Meta has heavily advertised as a key feature for their system. They position VR meetings as a replacement for video conferencing, saying that VR meetings 'Virtual reality sets you free – to be more present, more engaged and more yourself' [41].

#### 3.4.3 For employee training

Han et al. [28] identified several characteristics of mixed reality that makes it useful to utilize for professional training purposes. Firstly, MR enables the integration of virtual instructional content into real working environments. This enables situational cognition and experiential learning. Secondly, by providing diverse visual cues such as symbols, text, animations, and 3D objects, MR enhances procedural learning, making it easier for trainees to grasp complex tasks. Additionally, it was found that MR supports group learning by increasing the visibility of virtual content, allowing for shared learning experiences and improving accessibility. Finally, training made in MR deals with virtual artifacts, which are much cheaper to produce and modify than real-world artifacts, which can make training more efficient and affordable.

In a literature review conducted by Han et al. [28], from a sample of 51 publications on MR-supported instruction, the fields of engineering and health and medicine were the best represented. Examples of such research is using augmented reality to create a learning environment for basic life support [32], or using it for specific skill training, such as hand-assisted laparoscopic surgery [36].

#### 3.4.4 Status quo

With mixed reality systems such as Meta's Quest platform and Apple Vision Pro becoming more accessible to consumers over the last few years, early adopters have been experimenting with implementing these systems for work, and documenting their experiences.

One person, an editor for technology blog Ars Technica, used the Apple Vision Pro for their work for one week [3]. Axon [3] reported that "visionOS and its apps are mostly about flat windows floating in 3D space." They report a lack of relevant use cases for the device's 3D capabilities. Initially, Axon treated the device much like a traditional monitor

setup, arranging virtual 2D windows around their desk. However, after experimenting further, they adopted a novel workflow by assigning different rooms in their apartment for specific work tasks and placing relevant application windows in those spaces. For example, the dining room became a writing space, the office was for communication apps, the living room was reserved for media, and the kitchen became the planning area.

This approach allowed Axon [3] to physically move around their apartment while switching between tasks, mimicking the benefits of a standing desk but on a larger scale. They likened the experience to a "radical extension of the standing desk," noting that it kept their mental energy flowing in a way that staying at a single desk could not. By aligning certain tasks with specific spaces, they found a heightened sense of focus and creativity.

## 3.5 Conclusion and research gap

The fields of tangible user interfaces and rich user actions offer innovative perspectives on designing technology that aligns with our natural, embodied way of being. Yet, much of this research keeps up a representational view on digital information. While these papers acknowledge the extension of cognition into the external world through tools and artifacts, they keep up a fundamental division between content and the physical realization [66].

Moreover, these studies often seem to start with novel interaction techniques and tend to search for a specific application to use this technology for afterwards. However, If we aim to design better technology for work, we should start by understanding the unique requirements and characteristics of the job at hand, instead of starting with technology. This approach can guide us toward creating more specialized, effective interfaces tailored to the demands of specific tasks.

Previous interventions for increasing physical engagement in the office use behaviour change techniques to target the symptoms of sedentary work - offering reminders to stand up or walk, for example, without addressing the core structure of office tasks. "Active behaviour" in the context of these papers is often limited to standing or taking breaks, but does not fundamentally alter the nature of computer-based work itself, where embodied skills are mostly absent. In this research, I try to tackle the problem on a more fundamental level by redesigning the way we interact with computers to leverage our embodied skills more.

Spatial computing presents intriguing opportunities to rethink these interactions. However, current applications and literature primarily focus on collaborative design, remote meetings, and training, with limited innovation in applying these technologies to office tasks. Despite several challenges, the properties of spatial computing to bring computing into our lived environments seems promising for creating more embodied and skilled interactions with technology.

# Chapter 4 First Iteration, Contextual Inquiries

In their 2005 paper, Jensen et al. [35] observed and described the practices in the work of an operator doing routine testing of a bottle-filling machine. By doing this, they identified that the work done by the operator had a dance-like choreography. Where Jensen et al. [35] focused on identifying and utilizing the skill found in physically skilled work, the question in this study is if can we observe or find opportunities to (re)introduce similar elements of skill in the practices of modern office workers. Therefore, this first iteration of the RtD process is centred around immersing myself into the work context of office workers. To be able to contrast this with work practices of non-office workers, I also immersed myself in the practices of craftsmen.

# 4.1 Methodology

To immerse myself in current work practices, I observed subjects at work to gather qualitative data on how they interact with their current tools and physical space. The goal of these observations was to gain a clearer picture of the movement patterns, postures, and tool usage in real work environments. Pedersen et al. [51] (citing Dourish [15]) highlight the importance of looking at practices in context. Dourish explains that 'Context and content (or activity) cannot be separated. Context cannot be a stable, external description of the setting in which activity arises Instead, it arises from and is sustained by the activity itself' [15, p. 4-5].

Usually, when doing observations, a risk is that the information often gets too abstracted and summarized by the interviewer [5]. When doing interviews, a similar thing can happen with subjects abstracting their own practices. When only summarized experiences are shared, much of the relevant nuance is lost. Beyer and Holtzblatt [5] highlight the importance of observing detailed, everyday tasks. Being present during the actual work reveals these important details. Likewise, Jensen et al. [35] mention the importance of a detailed micro-level view on user actions, in addition to a wide-angle view of the practice when doing observational research.

The method that seems fitting for these observations is contextual inquiry, as developed by Beyer and Holtzblatt [5]. It is a combination of interviews and observations in context. During these observations, you aim to create a 'master craftsman - apprentice relationship' [5], as this creates the right mindset for both researcher and study subject to learn more about the work of the study subject. In addition to the contextual inquiry method, I will also apply the insights from Jensen et al. [35] and have an additional focus on micro-level view on physical user actions.

The contextual inquiries took place via one-on-one sessions lasting around one to two hours, where the subject performed their usual tasks while discussing them with the interviewer. This inquiry was organized into four phases, following Beyer and Holtzblatt [5].

#### Introduction

For the contextual interview, it was important that the subject was comfortable with the research procedure to elicit the right behaviours. I started the interview session with introducing myself and the goal of the research. After this, I reviewed the informed consent form with the participant, ensuring they read it thoroughly and had the opportunity to ask any questions before signing. Following this, I explained what I hoped to learn from the interview and indicated that I expected the subject to correct me if I made any misinter-pretations. To further explain in familiar terms how I hoped the dynamic between me and the subject would be, I explained that my presence could be seen as a micro-internship. Finally, the introduction part was wrapped up by asking their opinions on the tools they use for their work, and asked about the tasks they would be doing on that particular day.

#### Transition

Beyer and Holtzblatt [5] emphasize the importance of having a clear transition from interview to contextual interview, so that the new 'rules' or social norms are established. Therefore, at the transition point, I clearly explained that I will now be observing the subject at work, and that I will interrupt when I see something interesting. I also made sure to explain that the subject can ignore my question if it comes at a bad time.

#### The contextual inquiry

The bulk of the contextual inquiry consisted of observing the subject carrying out their daily tasks at work. The observations focused on both what the tasks are that are being done and how those tasks are done. In the observations, I took both a detailed (what are they doing with their hands, etc.) view of these tasks, and a more generalized view.

With observations come interpretations. To make sure these interpretations are accurate, I made sure to explain my interpretations while I made them to the subject, who could either confirm or correct them. I also interrupted when I saw something I did not understand, but tried to keep interruptions to a minimum.

#### Wrap-up

In the final stage, I reviewed the notes I took with the participant to ensure that the interpretations are correct. I thanked them for their participation, and I invited them to take part in the next part of my research.

### 4.2 Findings

The contextual inquiry was conducted with 11 subjects in several different organizations. Seven of the subjects had what I would classify 'office jobs'; they worked in an office on non-physical work using a computer as their main tool. These subjects were employed at three different organisations. Three subjects are employed at a small to medium-sized software development company (A)  $^1$ , three subjects worked at a housing cooperation (B), and two subjects worked at an organisation that works closely with the municipality to help execute the sports policy of the municipality and to manage sports facilities such as swimming pools and gymnasiums (C).

Within this group of office workers, I can make another classification. Some jobs are centred around the usage of a computer and would not exist if not for the computer. These jobs include the developers observed at organisation A and the data analyst working at organisation B. The other group also uses computers for the majority of their work but could exist without them (although they would look quite different). This group includes the employees of the communication department of organisation B, and the work of the activity coordinator and human resources manager of organisation C.

The other 3 subjects had a physical aspect to their work. These observations served as inspiration to find opportunities to make office jobs more physically engaged. These subjects, 2 carpenters and a barista, were all self-employed, with the carpenters working together on the same project and the barista working in a small-coffee bar he runs mainly by himself.

In the following section section, I present a structured overview of the observations done during the contextual inquiries. The full report on the observations per session can be found in Appendix A.

<sup>&</sup>lt;sup>1</sup>Disclaimer: I work at this company. While I do not expect a conflict of interest in the observations, I am much more aware of the work practices of my colleagues than those of strangers. This might influence the results of the contextual inquiry.

#### 4.2.1 Digital native jobs

#### Workspace configuration and tools

Subjects A1, A2, and A3 from organisation A (front-end and back-end developers) and subject B1 (data analyst) consistently use multi-monitor setups, with each program placed on each monitor deliberately. There seems clear attention for this organisation of the workspace.

Furthermore, it is notable that despite the flexible desk policy at organisation B, subject B1 unofficially claims a fixed workspace. This subject surrounds themselves with personal desk items, suggesting an effort to establish a personalized and stable workspace despite company policy.

#### Interaction with technology

Subjects A1 and A3 show a strong preference for operating their computer programmes with keyboard shortcuts over using a mouse. A3, in particular, uses arrow-key-based navigation extensively. On the other hand, subject A2 relies more on mouse-based interaction. One developer at organisation A commented that they consider developers who are able to use the keyboard as their main way of interacting with their computer, as generally more skilled.

Next to this, there are several digital tools all the developers at company A used, including Git for version control, an IDE (integrated development environment) to write code, and Gitea, an issue-board platform.

#### Physical interaction and posture

All subjects I observed worked while seated despite having access to standing desks. One notable observation was that A2 occasionally interacts with a football under their desk, suggesting a physical mechanism for stress relief or focus. I also noted that A2 and A3 lean closer to the screen during intense focus.

#### Collaboration and communication

At organisation A, in-person discussion is preferred when available (A1, A3), often initiated by physically rolling a chair to a colleague's desk. However, as this organisation has a hybrid work policy, digital tools such as Discord (voice and text) and Gitea (interface for using Git version control and work management) are central to asynchronous and remote communication across all subjects at organisation A.

#### Workflow structure

Subject A1, A2, and A3's workflows are all structured around Git-based task management (Gitea), using digital kanban boards to move tasks between statuses. When changes in the code are made, these changes are shared using Git. The subjects all used a GUI that was integrated into their coding application.

B1's workflow is more exploratory. Their work often requires investigating different possibilities and testing configurations within Power BI. A significant part of the participant's work involves managing and analysing columns of data within Power BI. They frequently utilize the tool's relational view, which employs a node-based database interface. This view facilitates the construction and visualization of relationships between data tables.

#### 4.2.2 Other office jobs

#### Workspace configuration and tools

Subjects B2 and B3 (communications roles at organisation B) and C1 (movement advisor at organisation C) typically work with dual-screen setups. B2 uses one screen primarily for Microsoft Teams and another for all other tasks. B3 dedicates one screen to communications and the other to various tools.

In contrast to the structured setups of developers, B2 and B3 exhibit a less systematized screen organization. B3 frequently adjusts overlapping windows and detaches and reintegrates application views depending on task requirements. C1 also actively rearranges application windows during work.

#### Physical interaction and posture

I was able to note several observations on the posture and physical movement between the subjects. Similar to the digital native jobs, the subjects remained seated despite having a standing desk. It was interesting that B1 occasionally adjusted their screen down to be able to have conversation with a colleague sitting opposite of them. I also noted that B3 leans forward when reviewing and relaxes while typing.

Next to observing C1 while working at their desk, I also observed them in a meeting. In organisation C, all meeting rooms contained standing desks, prompting a more active posture. Physical note-taking is central in meetings for C1, who also occasionally gestures with the pen they are holding while talking to help them explain something to the other person in the meeting.

#### Workflow structure

B2's workflow seemed structured and calendar-driven, emphasizing order and clarity in file and email organization, while B3's workflow seemed more reactive, often disrupted by interruptions and involving frequent task-switching.

#### 4.2.3 Physical (craft) jobs

#### Workspace configuration and tools

Subject D1 (barista) operates in a structured coffee bar where each element, such as the espresso machine, grinders, water station, and point-of-sale system, is strategically placed to support their workflow.

Subjects E1 and E2 (carpenters) work in a shared and reconfigurable space with fixed and movable tools. The environment is somewhat cluttered. Despite this, the workers are to make their way around the space by moving tools to prepare the space for their job.

#### Interaction with tools and materials

The barista (D1) demonstrates precise, skilled interactions with their tools. This is especially present in steaming milk, where sensory engagement (sound, touch) is crucial to achieve the right texture and temperature. This control and rhythm are developed through training.

A similar interaction can be seen in the work of the carpenters. They switch between power tools for rough work and hand tools for detailed tasks. Hand tools are preferred for tactile feedback and finish quality. Furthermore, the display frequent movement around the workspace, involving bending down, walking around, and repositioning materials.

#### Physical interaction and posture

At busier moments, D1 is almost constantly moving, combining standing, walking, and precise hand gestures. Similarly, E1 and E2 engage in substantial bodily movement, including lifting, ducking, and repositioning materials, reflective of the physical demands of woodworking.

#### Workflow structure

D1's workflow is defined by a clear sequence of tasks for each drink, a sequence that is optimized for repeatability. Interruptions (e.g., a customer coming in) requires D1 to switch between contexts.

Similarly, because of their limited workspace and the fact they work with pieces of wood that are large, the carpenters require constant spatial awareness and management of these materials. When a (sub) piece is done, it has to be placed on a specific location to make space for the next piece, which is a clear visual indicator of progress.

### 4.3 Interpretations

In this section, I will combine the observations gathered during the contextual inquiries and interpret them into themes and design opportunities. Some of these are straightforward observations that emerged across one or more inquiry sessions, while others highlight potential opportunities identified during the observation process. These themes and opportunities are mentioned in no particular order.

#### Usage of hands and fingers

One thing that was obvious in all observations in the office, is that there is very little bodily engagement or skill in the work. However, there is one exception to this. Most of the office workers I observed were touch typists. Touch typing exemplifies the kind of embodied skill that can be developed through practice. It showcases how the human body can adapt and optimize repetitive but dynamic tasks. The developers take this one step further, by controlling much of their computer with keyboard shortcuts only, also seeming to take pride into being able to do that.

All of the observed office jobs were primarily done using a personal computer or laptop using only input from the fingers. The rest of the body was mostly dormant. While the craftspeople I observed primarily interacted with their tools using their hands as well, the types of interactions were different. There are different motor skills involved, such as in the tamping of the coffee grounds into the piston by the barista, or the sanding of boards by the carpenters. In addition, these jobs were mostly executed while standing and walking around, instead of being seated all day.

#### Usage of legs

While our fingers are highly engaged in current office work, our legs are mostly inactive. An interesting observation was made with subject A2, fiddling with a football that just happened to lie around the office while working. It highlights an opportunity to utilize the feet as extra ways of interacting with our tools at work - something that is done skilfully in crafts such as sewing and pottery or in driving.

#### Usage of standing desks

All the office workers I observed had access to sit-stand desks, yet they admitted to using them rarely, if at all. This observation supports my suspicions that interventions like sit-stand desks are largely ineffective in promoting consistent and sustainable movement during work. The design should therefore add movement in a natural way, not as an afterthought.

In the meeting rooms at organisation C, there were *only* standing desks available, forcing an active posture while having a meeting. Not only does this promote standing, it also shapes a more active attitude during the meetings which seems to have an overall positive effect. I take from this an implication for the design of an intervention, not only does the design have to promote movement in one's job, it should do so in a way that feels like it contributes to help people reach their (professional) goals.

#### Attention for one's tools and workshop

All office-based organizations that I have visited have flexible desk policies, and every workspace looks alike despite the subjects doing vastly different things. The uniformity of workspaces disregards the unique identity and needs of various professions. In organisation B, you could see that despite the organisation having a flexible desk policy, people tended to gravitate towards more fixed spots close to their colleagues, with subject B1 even claiming their own desk against company policy. This observation aligns with Hertzberger's rationale behind the design of the Centraal Beheer offices in Apeldoorn [43].

At the other end of the spectrum, we find the 'office' of the barista. The tools and the layout of these tools have all been selected and place with a rationale. Talking to the barista about this, I could sense their pride and enthusiasm about this. Applying maintenance on their tools is an integral part of their work and helps create the best work output for them. This attention and care for one's tools is something that is core to the practice of 'Shokunin', a Japanese expression for a skilled craftsman [46]. Helping office workers create a similar kind of attention for their tools and workplace might help them in getting a stronger professional identity and help support craftsmanship-as-a-practice.

#### Physical specificity of tools

Despite observing a wide range of tasks during the contextual inquiries, the tools used were remarkably uniform: input was limited to a mouse and keyboard, while output relied on one or more screens displaying a windowed GUI. I've previously discussed how Cartesian thinking frames this as the most logical solution. However, this generalist approach to designing tools may not be the most effective way to support the diverse needs of these roles. For instance, the requirements of someone coding differ significantly from those of someone managing emails. Following this reasoning, tailored tools that align more closely with the specific demands of each task could improve the worker's experience.

#### Spatiality and task separation

During my contextual inquiry, most of the people I observed were focused on a single specific task at any given moment. However, they mentioned that their workdays involve various responsibilities and activities. In the organizations I visited, meetings were typically conducted in separate rooms, but all other tasks—regardless of their nature—were carried out at the same workstation, seated behind a computer.

This contrasts sharply with the three non-office jobs I observed. Take, for example, the barista: every step of their job, from serving a customer to steaming milk, occurs in a different physical location. Each task involves distinct physical interactions and movements. This spatial separation inherently structures their workflow and creates variety in their day.

Office jobs could potentially benefit from a similar approach to spatially segmenting tasks. Introducing distinct physical zones for different activities might not only promote a more active workday but could also aid in mentally separating tasks, enhancing focus and productivity. Perhaps office jobs can benefit from this spatial separation of tasks. Not only might this create a more active work day, it could also help mentally separate tasks to improve focus.

#### Version management and work-in-progress

Digital workflows unlock the ability to manage multiple versions of a file simultaneously, allowing for easy iteration, branching, and reversion. These capabilities are fundamental to modern work practices. A single file can have an infinite number of copies, making it possible to experiment freely without the risk of losing previous work.

This is central to software developer workflows, where Git, a distributed version control system, tracks and stores changes across multiple locations. While these repositories represent actual storage locations, interacting with Git can feel highly abstract, particularly for new developers.

In contrast, craft work lacks version control but makes work-in-progress highly tangible and visible. A carpenter's half-finished chair physically occupies space in the studio, serving as natural reminders of ongoing work. These artifacts exist within the workspace, making progress intuitively accessible. In digital workflows, however, unfinished work often remains hidden, stored as commit histories, draft emails, or files with name extensions such as '...v1', '...final', or '...def', rather than visible artifacts.

#### Tool management as thought management

On all major computer operating systems, a window-based paradigm is used to manage applications (tools). Windows can be brought to the front, sent to the back, arranged side by side, or even minimized into what feels like a digital void. This behaviour has become the default expectation for how computers operate and has shaped the way we think and work with them.

In observing subject B3, their window management seemed to act as a form of scaffolding for their thoughts. Windows were arranged in ways that supported their workflow; sometimes placed side by side for direct comparisons, sometimes overlapping for quick reference. However, there were moments when the sheer number and arrangement of windows appeared to overwhelm them, indicating a potential cognitive burden imposed by this system.

In contrast, the tools used in physical jobs are bound by the constraints of the physical world. These tools cannot simply disappear into a void; they must be stored, retrieved, and used within the confines of a tangible workspace. This inherently limits the number of tools accessible at any one time, encouraging slower, more deliberate use. This contrast between digital and physical tool management highlights an opportunity to rethink how digital environments could support skilled interactions. By drawing inspiration from the intentionality and spatial limitations of physical tools, it may be possible to design interfaces that support conscious and skilful (digital) tool usage.

#### Moving closer for focus

One consistent observation across all subjects, whether office workers or not, was their tendency to subconsciously move closer to their work when focusing. Interestingly, this occurred even when content on the screen could easily be resized for better visibility. While this behaviour might initially seem to be about seeing the task more clearly, it suggests a deeper significance in the physical proximity between the body and the work.

This observation points to a potential connection between physical closeness and engagement, where the act of moving closer may enhance focus or create a sense of immersion. An implication for design can be to explore how the body's relationship to (digital) content can be leveraged in meaningful ways.

## 4.4 Design concepts

Building on the contextual inquiries and the identified themes and opportunities, I developed a set of design concepts that utilize spatial computing to explore ways to add embodied skills into the office. Some of these concepts are very general, while some of these are more concrete. These concepts will serve as a foundation for the second phase of this research, where selected ideas will be explored and refined in more depth. Each concept will be briefly described with references to the themes and opportunities they are based on.
#### Computer programs as tangible tools

As I noted in Section 4.3, computer programs have their own window-based paradigm that has become the default way in which we have come to expect computer programs to behave. They are windows on a 2,5-dimensional plane that one can resize, move around, and bring to the front or back. I also observed in this section that the way these windows are actively organised seems to scaffold some cognitive processes.

In early XR operating systems like Apple's visionOS and Meta's Horizon OS, this windowbased paradigm has been extended into a three-dimensional space. While understandable, given the familiarity of this approach for users, designers, and developers, these early implementations miss an opportunity to fully leverage the spatial possibilities offered by XR.

A direction for design is to explore how the three-dimensional space in spatial computing can improve interactions with digital tools. Even if most professional applications remain fundamentally two-dimensional, there is potential to rethink how users interact with and organize these tools. Drawing inspiration from physical tools could transform how programs are stored, retrieved, and used. For example, programs might need to be "stored" in specific spatial locations when not in use and "retrieved" like physical objects. Active programs could require placement on virtual surfaces rather than floating freely, and instead of overlapping arbitrarily, they could relate spatially to one another. By enhancing digital tools with "physical" properties, we could mimic the organizational and cognitive benefits of physical tools, creating more intuitive and engaging workflows.

#### The body as focus controller

In Section 4.3 I observed how universally, when trying to pay attention people move closer to their work. Even if the computer offers them different ways to get a better view of their work. This suggests that the physical positioning of our bodies in relation to our work carries inherent meaning and plays a role in how we engage with tasks. Similarly, I noticed some individuals using their cursor to highlight lines of text as they read, mimicking the way we might use a finger to guide our eyes across printed text.

This interplay between body positioning and focus presents an opportunity for design. For instance, we could leverage this instinctive behaviour to create interactions where body movement directly controls digital content. Here I imagine a large virtual canvas where one's physical proximity determines the level of detail: moving closer to the canvas "zooms in" on specific sections, while stepping back provides a broader overview.

#### Skilled text manipulation

Like I mentioned in Section 4.3, one area in office jobs were I was able to observe embodied skills in use, was text input. Touch typing is a prime example of a embodied skill that can be obtained by training. For developers, the ability to navigate code editors using only

keyboard shortcuts not only enhances productivity but also reinforces their professional identity. However, these embodied skills primarily engage the fingers, leaving the rest of the body underutilized.

This observation presents an opportunity to explore new ways of selecting and manipulating text that engage more parts of the body. For example, a gesture-based system could expand on the existing skill of touch typing, allowing users to skillfully and efficiently interact with digital text through dynamic bodily movements. Such a system would need to provide direct control, where gestures immediately and intuitively affect the text, avoiding the abstraction of gestures as mere "commands." Just like touch typing, a gesture system forms a language that needs to be learnt. However, if the system enables smoother, more intuitive interaction with digital tools, it may be worth it for people to learn.

#### Foot controls

Building on the concept of engaging the body more fully in digital tasks, as discussed in Section 4.3, an interesting opportunity exists to explore the lower extremities as a means of controlling digital tools. Currently, input devices like the mouse and keyboard primarily engage the hands, leaving other body parts largely inactive during work. Introducing footbased controls could help distribute the physical engagement across the body. The concept should not fully replace traditional input methods, but rather complement them, much like how a sewing machine uses foot pedals in combination with hand movements to operate effectively.

Just like I mentioned in the previous concept, foot controls should engage the legs in a dynamic, interactive way that supports or becomes part of a new, active sensorimotor loop. Just as in other forms of embodied skill, this would allow the user to develop a kind of fluency in operating their device.

#### Spatial workstations

As previously mentioned in Section 4.3, with the introduction of flexible office spaces, much of the meaning and personality of one's workstation has been lost. The workspace of a developer now looks nearly identical to that of a communications specialist, despite their vastly different roles. Furthermore, as highlighted in Section 4.3, many jobs require a wide range of tasks, often of entirely different natures, that all occur in the same physical location, leading to a lack of spatial differentiation.

I believe there is value in consciously shaping one's workspace, such as I observed in the space of the barista. Organising ones tools in one's workspace, creating one's own 'studio', could help shape craftsmanship-like attitudes. Furthermore, having tools dispersed through a workplace, instead of all centred around one desk, will add more movement into one's day, and will create a greater task separation, potentially helping with focus. Spatial computing could offer a great opportunity to shape such a 'studio' in a digital manner, similar to how Axon [3] explored how moving his different application windows into different spaces, something similar could be explored for office workers. This concept could allow workers to "design" their digital workspace in a way that mirrors the intentional organization found in physical environments.

#### Tasks with dimensions

Tasks with Dimensions is a concept that draws inspiration from the physicality of nonoffice jobs, where tasks are often large, tangible, and directly tied to materials, providing a clear sense of progress, as previously discussed in section 4.3. The idea is to create a task management system in spatial computing that brings the physicality of large tasks into the digital space, making intangible tasks more concrete and graspable.

In this system, tasks are represented by virtual objects or 'items' that exist in a 3D space, and their size could correspond to the complexity or significance of the task. For example, smaller tasks might be represented by small, simple objects, while larger, more complex tasks would be represented by larger, more substantial objects. Users can interact with these objects in space, taking them from one location (such as a 'task pile' or 'to-do area') to the designated 'work area.' When a task is completed, the object must be moved to another area, perhaps a 'completed tasks' space, symbolizing progress and providing a visual representation of the user's accomplishments.

This approach leverages spatial interactions to give users a tactile, embodied sense of task completion. The act of physically moving tasks around in a virtual environment mirrors the movement of materials in physical jobs, providing a more engaging, interactive experience. As tasks are completed, the space could evolve—task objects being physically manipulated and organized into meaningful patterns. This would not only help organize the workflow but also provide a constant, visual sense of progress. The dimensionality of tasks in this system would create an immersive, intuitive way of managing work that taps into spatial cognition and physical engagement.

#### **Spatial Git**

Building on the observation made in Section 4.3 that Git version control can feel abstract, particularly for new developers, this concept aims to make version management more intuitive and less abstract by incorporating spatial interactions. The idea is to transform the process of controlling Git into an embodied experience where users engage physically with their workflow in a more conscious and deliberate way.

In this concept, Git actions such as committing, branching, merging, and pushing/pulling would be represented by distinct spatial actions, each associated with a specific gesture or movement within a virtual or physical environment. For example, a user might 'plant' a

new branch in the digital space by placing an object or marker in a designated area, mimicking the act of branching in the code. Committing changes could be represented by a specific hand gesture that "locks" the code in place, while pulling or pushing changes could be mapped to movements or actions that mirror the idea of retrieving or sharing.

This interaction could reduce the abstraction of Git, helping developers form a more tangible connection with the system. It turns the process of version control into a mindful activity, where the user becomes more aware of the changes being made and the state of their project.

## 4.5 Reflection on iteration 1

The design concepts that emerged represent an exploration of opportunities identified during the contextual inquiries. This reflection critically examines the contextual inquiries, which form the underlying assumptions of the proposed concepts. Furthermore, I will reflect on the concepts themselves, analysing what they mean for this research

Engaging with participants across a variety of professional roles provided valuable insights into how people interact with their work environments. When explaining the subject of my research, introducing more skilled movement into sedentary jobs, all participants not only understood its significance but also reaffirmed its importance.

Interestingly, craftsmanship-like attitudes appeared more pronounced in roles such as data analysts and coders compared to other office professions. These roles often involve creating a tangible (albeit digital) artifact quite independently, which already might foster a stronger sense of ownership and skilful engagement despite the job not having other craftsmanship-like qualities such as physical engagement.

The observations were limited in scope and detail. Due to time and situational constraints, I could only capture fragments of 1 to 2 hours of each participant's workday. This means that my understanding of their work processes is incomplete and may not fully represent the complexity of their roles. Furthermore, the subjective nature of observations introduces a layer of interpretation, which is influenced by my own biases and assumptions.

This bias might have been especially evident when observing participants in roles I was already familiar with, including my own colleagues. Pre-existing knowledge and assumptions about these roles may have shaped how I perceived and recorded the observations. While familiarity provided context, it may also have obscured nuances that a completely neutral observer might have noticed.

While I aimed for a master craftsman-apprentice relationship between me and the subject while doing the observations, the social dynamics were sometimes a bit different. However, by introducing the contextual inquiries as micro-internships to the participants, the goal of the contextual inquiry was pretty clear to most participants. Overall, while not painting a complete picture, the contextual inquiries provided a strong foundation for identifying key themes and opportunities, which guide the design concepts and future directions of this research.

The design concepts developed during this phase all address various facets of office work. Office work cannot be reduced to a single activity or routine; instead, it consists a diverse range of tasks and workflows. The variety of office jobs makes it challenging to decide how general or specific these concepts should be. If the designs aim to fit all the jobs I observed, they become more general. However, one of the main problems with modern computing is its 'one-size-fits-all' approach, where tools do not meet the unique needs of different jobs. This means there is a risk that creating something too general could repeat the same mistakes.

Creating skilled embodied interactions for knowledge and office jobs that are not 'afterthoughts' but are a natural addition to the job, proved to be difficult. Unlike physical work, where tools and tasks naturally engage the body, office work often centres around abstract and intangible tasks. However, the goal of this research is not to fully replicate physical labour but to expand the range of embodied skills involved in managing daily work activities.

The design concepts vary in their focus and scale. Some emphasize small, detailed interactions designed to cultivate and leverage embodied skills, such as skilled text selection or foot controls, while others adopt a broader perspective, such as Spatial Git and Spatial workstations. Both approaches have their value: the smaller interactions have the potential to refine individual workflows and add embodied skills, while the larger concepts present possibilities for reshaping how office work is approached. In the next parts of this research it may be possible that elements from different concepts may be combined or that smaller concepts may be incorporated into the larger design concepts.

All the design concepts presented are initial ideas that require further exploration. They serve as starting points for deeper ideation and will be developed and refined through bodystorming sessions in the next phase of this research. However, due to time constraints, it will not be possible to pursue all the concepts in detail. A selection of the most promising concepts will be made, based on their potential value and practical considerations, such as feasibility for further development.

# Chapter 5

# Second Iteration, Exploratory Bodystorming

The goal of this phase is to further explore the design concepts generated in the first iteration. Given the spatial and movement-focused nature of this research, traditional design and ideation methods such as sketching or brainstorming on paper, are not an ideal fit. These ideas are better understood through physical experience rather than abstract thought. Therefore, I will further develop the concepts using bodystorming techniques, which allow for an experiential and hands-on approach to ideation.

For the exploration I have selected three concepts from the first iteration to explore further. These concepts were selected based on their estimated potential and to make sure a variety of different concepts are selected for this phase. *Spatial Git* was selected in order to explore the potential of spatial computing to make abstract concepts more tangible, and because it encompasses a specific part of work that is present practically everybody who is working with software, making a design more universally applicable but still specific enough to focus on in this context. For that same last reason, *Skilled text manipulation* was selected as a second concept to explore further, as anyone using a computer deals with text input and manipulation, no matter the job. Furthermore, it presents a very direct and simple backdrop to implement embodied skills into the workflow of users. Lastly, I will explore the opportunities of *Spatial workstations*. While this concept leans less into the concept of embodied skills, it does potentially make more use of the unique qualities of spatial computing and aligns with findings in theory.

Bodystorming is mentioned widely across literature in the context of design focussed on movement and skill [47, 55, 37, 73, 45]. It encompasses brainstorming activities that rely heavily on bodily and situational engagement, involving several design techniques, each with its own purpose and strengths [73]. These techniques range from simply immersing oneself in the context in which the design will be used while designing a product, to

improv-theatre-like design methods [55].

Bodystorming can involve co-design with (potential) end users, but does not always have to. Both approaches have their advantages and disadvantages. Working with end users might produce more realistic designs, but these people are at risk of falling into fixed patterns of failing to think too much outside of the box. Furthermore, it is crucial that participants feel comfortable moving and expressing themselves during bodystorming sessions [70]. This comfort is more likely when participants have an established relationship with the session leader, feel at ease using their bodies (whether through hobbies or professional experience) or are already familiar with bodystorming and ideation techniques.

The three concepts selected for this phase are all quite different in nature. *Spatial work-stations* requires a very personal approach to managing one's workstation, and is not very experimental. Because of this, it makes sense to explore this concept with end users in their natural workspace. *Skilled text manipulation* has a high emphasis on exploring physical skills and doesn't require specific domain knowledge. Because of this, it makes sense to explore this concept with participants who have more experience with skilled movement. On the other hand, exploring *Spatial Git* does require specific domain knowledge. Therefore this session with be conducted with people who have knowledge about software development.

## 5.1 Bodystorming techniques

There are clear links between bodystorming and theories on embodied cognition and phenomenology. These links are stronger in some bodystorming techniques than in others. One thing that is present in most is the acknowledgement of the importance of the lived body in experience design.

Schleicher et al. [55] criticise common forms of bodystorming from the embodied perspective. They state that techniques such as 'use-case theatre' (using actors and props to simulate and explore how a product will be used in real-life scenarios) and 'strong prototyping' (involving creating a physical simulation of the intended environment to test and refine a product's design under realistic conditions) fall short as they are just creating 'simulations' of the real world. They are also subject to groupthink and do not enable us to quickly generate strong concepts.

Bodystorming techniques that are more aligned with theories of embodied cognition include embodied storming [55], moving and making strange [37], and embodied sketching [45].

**Embodied storming** [55], unlike other bodystorming methods like strong prototyping or use-case theatre, which involve more structured environments or scripted role-playing, focuses on spontaneous action and collective discovery. Strong prototyping tests design

ideas in highly detailed, simulated settings, and use-case theatre involves acting out specific roles to simulate user interactions. In contrast, embodied storming is about creating a space for unfiltered, real-time engagement, where participants learn through doing rather than planning. This approach emphasizes physical, tacit knowledge over abstract ideation, helping designers gain more immediate insights into the user's experience.

Embodied storming [55] begins by identifying a specific scenario within a certain context for the product being designed. Participants engage in this scenario through improvisational play. This improvisation is key to embodied storming: participants act and respond instinctively, exploring actions that feel natural or intuitive to them rather than following a pre-scripted sequence. This "act first" approach encourages people to rely on their physical and emotional reactions within the space, which often brings out insights about ease of movement, intuitive interactions, and potential friction points. Throughout the process, facilitators observe closely, taking note of body language, moments of hesitation, or unexpected interactions. After the activity, participants and facilitators discuss what felt intuitive, challenging, or surprising. The emphasis is on the experiential insights that arise from physically interacting within a context rather than analysing abstract concepts.

Strongly rooted in phenomenology, the **Moving and Making Strange** technique [37] is a variant of bodystorming that involves performing movements in unusual ways, such as changing speed, direction, or initiating movement from an atypical part of the body. By "making strange," participants gain a fresh perspective on bodily movements, which can uncover novel insights for designing movement-based interactions. It emphasizes the firstperson, experiential aspect of movement, where the body's role in perception and cognition is central.

Loke and Robertson [37] describe seven activities as part of the methodology, each with a different purpose. For the exploratory phase of this research, the first two activities are most relevant. The third, fourth, and fifth activities are used to analyse the exploration, and the sixth and seventh activities are used to move towards a design. While the later steps might prove useful in later phases of this research, I will first touch upon the first two activities in this section.

The first activity, investigating movement activity involves exploring basic movements to gain first hand experience of bodily actions. One might try different ways of performing simple actions by varying speed, scale, or intensity. This process helps gain a deeper awareness of movement dynamics and the sensations they evoke, which can reveal insights into what makes certain movements feel intuitive or challenging.

The second activity, inventing and choreographing movement, involves creating and experimenting with new movement patterns, either inspired by parameters or qualities of movement, or by words, images and concepts. Using parameters like timing, direction, and spatial arrangement, they can choreograph movements that embody specific qualities or emotions.

In comparison to embodied storming, which aims to simulate realistic, familiar con-

texts for practical insight, Moving and Making Strange [37] is more exploratory, focusing on how familiar bodily movements can be transformed to inspire design innovation. It uses an experimental lens, altering familiar movements to break conventional thinking and reveal novel interaction possibilities.

**Embodied sketching** [45] is a bodystorming technique which is intended to focus more on ideation than evaluation of ideas. It aims to include the bodily (somaesthetic) experiences in the design process before the development of actual prototypes. It differs from the other bodystorming techniques by focussing on simple actions that are constituent to the bodily activity designed for ('sketches'). It can be used in several scenarios, both for designers to think of few ideas from scratch, to involve stakeholders through co-design, and to help sensitize designers to a certain phenomenon.

A key element of embodied sketching is the way it uses the entire physical environment as an active design resource. While other methods might treat the setting as a passive backdrop against which ideas are evaluated, embodied sketching encourages designers to incorporate contextual elements into their process.

Furthermore, in embodied sketching, hands-on engagement is encouraged. Designers interact with each other physically and without a predetermined script. This approach to ideation is open-ended, allowing designers the freedom to move through their surround-ings and respond spontaneously. This is a departure from more structured techniques that may require designers to adopt specific roles or follow strict guidelines.

Movement and playfulness are core to the embodied sketching process. Play is not only a method but a goal in itself. Unlike other embodied ideation techniques that may rely on staged scenarios or controlled settings, embodied sketching uses the power of play to free designers from conventional thought patterns. This playful aspect is similar to improvisational theatre but is tailored for physical engagement in the design process.

Finally, embodied sketching emphasizes creating an environment that is beneficial to sensory engagement and creativity. Rather than focusing immediately on prototype testing, as other methods might, embodied sketching aims to explore ideas at a more experiential level during the early ideation phase. This approach seeks to expand the design space by allowing designers to experiment freely, which can lead to richer outcomes.

# 5.2 Spatial workstations

The goal of this bodystorming session was to explore how individuals can design their ideal spatial workstations to better reflect their roles, tasks, and personal preferences. The session aimed to uncover how creating one's spatial computing workspaces might enhance both movement during the day and work satisfaction.

#### 5.2.1 Methodology

The core activity involves designing a new 'spatial' workstation for the workflow of that participant. When preparing this session, I was deliberating between an approach where the participants would design this workstation using an mixed reality headset, or using a lower-fidelity paper approach for it, with pieces of paper representing application windows. Both come with their own advantages and disadvantages. Using the mixed reality headset would show the participants the possibilities of spacial computing, and it helps participants think beyond traditional 2D work setups and it would help them imagine new possibilities enabled by spatial computing. However, it would also present a steep learning curve and would come with some technical limitations. In addition, the novelty of using mixed reality could present a major distraction from the session. Participants might focus more on learning the tool than thinking about the spatiality of their workstation.

In order to answer this question, I did a pilot session by myself where I tried out both options. Furthermore, I consulted an expert who has experience with using mixed reality with first-time users. He emphasized that using MR in this case may not be the worth the distraction it causes from the main goal of the session. Therefore, I decided on a hybrid approach where first I gave give a short demonstration of the possibilities of spatial computing in a short demo environment that is already created, to put them in a certain mindset. Afterwards, the rest of the bodystorming session was be done using the physical pieces of paper with the name of the program written onto it, that could be moved around by the participants.

The session began with a brief introduction to set the context. Participants were informed about the purpose of the session and how their input informs the design concept. Examples of thoughtfully designed workspaces such as a barista's organized station or a restaurant kitchen were mentioned to illustrate the potential of intentional workstation design. After this, the participants were exposed to the concept and possibilities through a short mixed reality demo.

To ease participants into the activity, they first engaged in a warm-up exercise where they reflected on their current workspaces. They were asked to consider what aspects they find helpful or hindering and how their setup supports, or fails to support, their work. Furthermore, they were asked to create a list of tools or computer programs they use while at work. This list served as the foundation for the main activity.

Participants were be provided with pens, paper and painter's tape to represent their digital tools. Using these, they were asked plan a workstation layout tailored to their specific tasks and tools, emphasizing spatial organization and zoning for different activities. While doing this activity the session leader was be present and probed them to reflect on their choices and to share their thought processes aloud.

These bodystorming sessions were performed with five participants and lasted between 15 and 30 minutes each. Three of these participants were the same individuals who were

part of the earlier contextual inquiry sessions at the office spaces. Their familiarity with the research focus and their diverse work roles make them ideal contributors to this activity. The sessions took place at the participants' workplaces to ensure the designs are grounded in their real-world environments and to allow them to reflect on their existing setups.

#### 5.2.2 Pilot test

To ensure the feasibility of my approach and to refine my method, I first conducted a solo pilot test. This revealed two key limitations of the paper-based approach. First, while using the physical space of the room was effective, I could only stick items to existing surfaces, limiting my ability to place them in three-dimensional space in a way that is possible with mixed reality. Second, I found that I needed a way to position items upright rather than flat or against surfaces. Furthermore in noticed that by making use of the current elements in the space, the tools become tethered to my desk, which reinforces my tendency to centralize everything rather than distribute it across the workspace.



Figure 5.1: Artefacts of the pen-and-paper pilot session

After this initial pilot test, I recreated this workspace in MR using an Meta Quest 3 and the Fluid application. This application lets you create a large number of floating browser windows that can be put into space. Managing these browser windows and navigating to these different websites was quite a hassle. Using the virtual keyboard to navigate to the correct URLs and then using the controllers to move the windows in the correct position took some time to get the hang of. However, once the windows were in the correct



Figure 5.2: Artefacts of the digital pilot session

position, it did give a more realistic impression of how such a workspace would look like, as can be seen in in Figure 5.2. Another downside of this is when we show a high-fidelity impression of the user's current applications, we are fixed to the current way of thinking about computer tools as 2D windowed apps. By using the more abstract pieces of paper, this is less prominently the case and people might be thinking more freely. Because of these reasons, the decision was made to continue with the paper-based approach.

### 5.2.3 Findings

The sessions revealed a variety of spatial strategies employed by participants to organise their digital tools in a mixed reality (MR) workspace. While each participant approached the exercise in a unique manner, several recurring patterns emerged. These findings are integrated below, while a report on each session individually, along with a table of the resulting spatial setups can be found in Appendix B.

#### Central tools as anchors

Participants consistently designated one core application as the central anchor of their workspace. This central tool often reflected the primary focus of their daily workflow. For example, the HR manager (Session 1) placed her email client centrally, reflecting its importance as her main communication channel. Similarly, the communications advisor (Session 3) structured their space around MS Word, identifying it as the locus of their

writing tasks. The data analyst (Session 5) placed PowerBI at the centre of their layout, citing its central role in daily data work. These tools were typically positioned directly in front of the participant's sitting or standing location.

#### Functional clustering of supporting tools

Tools that are frequently used together were often grouped spatially, forming functional clusters. In Session 4, the movement advisor grouped Excel, HDI, and PowerPoint on the same wall due to their frequent combined use. Similarly, the HR manager (Session 1) stacked related tools along one wall, distinguishing those that required occasional checks from more action-oriented tools.

#### Use of physical distance to structure interaction

Spatial distance was used by several participants as a strategy to regulate attention. For instance, the HR manager (Session 1) positioned MS Teams behind her to encourage physical movement and limit distraction. In Session 3, communication tools such as WhatsApp and MS Teams were deliberately placed in a separate, booth-like area to prevent constant interruptions.

#### Temporal use patterns reflected in placement

Participants' spatial arrangements were also influenced by how frequently tools were accessed throughout the day. The communications advisor (Session 3) considered email and calendar as essential but non-continuous tools, placing them opposite the central workspace to promote intentional engagement. In Session 4, the participant preferred to stand when using tools accessed sporadically, such as Google, and to sit when using tools that required extended focus, such as Word.

#### Spatialisation of mental models

Some participants conceptualised their tool layout as a reflection of their internal workflow structure. The communications advisor (Session 3) described their final layout as a spatial expression of how they mentally organise tasks. Similarly, in Session 4, the participant compared her tools to books on a shelf; grouped by purpose but not tied to fixed positions. The data analyst (Session 5) created a menu bar of secondary tools, mimicking a desktop operating system. These examples highlight how existing digital metaphors and personal mental models inform spatial organisation in MR environments.

#### Influence of workspace context on engagement

The physical environment played a notable role in shaping participant engagement with the bodystorming activity. Participants in meeting rooms (Sessions 3 and 5) appeared to adopt more deliberate and structured approaches to tool placement compared to those working in flexible desk settings. For instance, the participant in Session 2, who worked in a non-personalised flexible workspace, engaged less reflectively with the exercise. In this session, the participant also used sticky notes in place of larger papers to her own suggestion, effectively turning applications into icons rather than windows, which limited spatial reasoning.

#### 5.2.4 Interpretation and reflection

The bodystorming sessions revealed a diverse range of results, each session offering insights into different aspects of the concept of having one's software tools spatially laid out in one's workspace. The method used during these sessions facilitated engaging discussions and evaluations of how tools are spatially organized. However, while the approach successfully sparked interesting conversations, it also had several limitations that need to be addressed for a more effective exploration of workflows and tool management.

#### Diverging approaches to spatial tool layout

Some participants fully embraced the idea of having their tools spatially distributed, while others adhered more closely to a traditional desktop metaphor, arranging their tools in a two-dimensional manner that mirrored conventional digital workspaces. This difference suggests varying levels of openness to alternative spatial interfaces. Some participants saw the spatial distribution as an opportunity for workflow optimization and reduced distractions, while others preferred familiarity and efficiency within a constrained digital space.

#### Tool organization strategies

The participants showed different strategies for their tool organisation. Some participants structured their tools based on the frequency in which they are used (B4, C1, B1), while other participants (C2, B2) seemed to structure their tools in a more conceptual way, such as putting communication apps in a 'phone booth' or having the calendar on a central wall. Only one participant (B2) decided to place their windows in different rooms, which suggests that most people still think within the boundaries of their immediate workspace.

#### Impact of physical work environments

The variety in work environments, ranging from fixed desks to flexible desk setups to no desk at all, provided an opportunity to explore how physical workspace arrangements influence tool organisation and prioritization. All of the participants centred their setup around a focus point, even if there was no natural central point present. Those with fixed desks tended to anchor their setup around their workstation, while participants without a designated desk still created a conceptual centre around their 'most important' tool.

#### Intentional extra movement

Some participants incorporated deliberate extra movement into their tool placement (e.g., placing infrequently used tools further away to encourage physical movement) (C1, C2), while others preferred more static arrangements. This seemed to align with the ideas and values of the participants, as company C is involved in stimulating active behaviour as part of their company goals.

#### Limitations of the bodystorming method

Reflecting on the method used, there are some key apparent limitations. While these sessions provided interesting insights into how participants spatially organize their digital tools, they may not fully align with the traditional definition of bodystorming. Participants were asked to arrange their digital tools within their workspace, but this activity was largely reflective and analytical rather than experiential. Although some participants physically moved to place tools in different locations, the outcome of this setup seemed to be that participants externalized their mental models of tool usage, rather than enact work scenarios in a bodily manner.

Additionally, the way tools were placed within the room was constrained by the scaffolding of the exercise. Since participants were only given the option to place tools on existing surfaces, there was limited opportunity to experiment with three-dimensional space.

Furthermore, because I sustained the traditional windowed application paradigm, I did not explore opportunities for spatial computing to go beyond this. By maintaining the conventional structure of desktop-based applications, the sessions largely reinforced existing mental models rather than challenging participants to rethink digital workspaces in a more distributed way.

This last issue remains a difficult general issue for co-designing and co-exploring new ideas that are so close to participants' daily lives and experiences. Because participants are deeply familiar with existing digital work environments, their expectations and habits are shaped by these conventions. As a result, introducing radically new spatial computing concepts without a direct reference to familiar paradigms can be challenging. When codesigning within such a context, there is a risk that participants will default to what they know rather than fully engaging with speculative possibilities. This tendency limits the extent to which new ideas can be explored, making it difficult to break away from incremental adaptations of existing systems. Future sessions could address this by incorporating more hands-on interactions or by gradually introducing more disruptive design elements to help participants step outside their current ways of thinking.

# 5.3 Spatial Git

The goal of this bodystorming session was to explore how de-abstracting the process of Git version control, something that traditionally very abstracted, can enhance developers' connection and understanding of the underlying workflow while also incorporating more physical movement into their tasks.

#### 5.3.1 Git explained

Git is a distributed version control system designed to track changes in files and facilitate collaborative work on projects. It enables the management of a project's history by creating snapshots, known as commits, which record the state of files at specific points in time. This functionality allows for version tracking, error recovery, and experimentation by preserving previous iterations of the work.

Additionally, Git supports parallel development through branching, enabling different lines of work to proceed independently and be integrated when necessary. By maintaining repositories locally and synchronizing with remote repositories, Git ensures consistency and coordination in collaborative environments, making it a foundational tool in software development and version management.

The typical way of interacting with Git is through command-line commands, but nowadays most coding tools provide a graphical user interface to manage Git. Git provides a set of commands to manage version control, from staging changes to pushing and pulling updates between local and remote repositories. What follows in the rest of this section is an overview of the most common concepts in Git.

#### Locations and concepts in Git

- Working Directory: The working directory refers to the local folder in which a user actively manages and modifies files. It functions as the workspace or draft area where changes are made prior to formal documentation or commitment.
- Local Repository: A storage location on the user's local machine where the Git system maintains the project's history. It is a log of the changes.
- **Remote Repository**: An online version of the repository, typically hosted on platforms such as GitHub, which facilitates collaboration among multiple users. It operates similarly to a shared cloud folder, providing access for team members to contribute to the project from various locations.

• **Branch**: A branch represents an independent line of development within a repository, enabling users to isolate changes and experiments from the primary codebase, typically referred to as the "main" branch. Each branch operates as a distinct version of the project, with its own history and modifications, which allows for simultaneous development activities to occur.

#### **Common Git actions**

The Git version control system comes with a list of actions or commands, that serve different purposes in the system. What follows here is a list of the most common actions, the actual list of possible actions is much longer.

- git init: Initializes a new Git repository.
- git clone [repository]: Copies an existing repository from a remote location to the local machine.
- git commit: Finalizes changes and stores them in the local repository.
- git push: Uploads the commits from the local repository to a remote repository.
- **git pull**: Downloads and integrates changes from the remote repository to the local repository.
- git checkout Adds a specific branch to the working directory.
- git merge Combines two branches.
- git log: Shows the commit history.
- **git fetch**: Retrieves changes from a remote repository without merging them. It's like checking for new entries in the shared folder without actually adding them to your project yet.

#### 5.3.2 Methodology

The sessions started with an introduction to the concept and explaining the goal of the session. Together with the participants, a list of Git actions and their meanings was constructed which served as input for the bodystorming activity.

The bodystorming activity involved participants engaging with the idea of spatial Git interactions through embodied sketching, following the technique described by Márquez Segura et al. [45]. They were asked to act out Git actions in a spatial context, using just their bodies. Participants experimented with various gestures and movements, iterating on how these can best represent Git actions.

Through pilot testing I found out that in order to facilitate this exploration, I needed a way to quickly 'save' such a sketch and refer back to it later. To do this, I developed a



Figure 5.3: Webpage containing 'sticky notes' to quickly save and play back an embodied sketch

simple webpage that uses the webcam to record a short video to a video sticky note, which can be seen in Figure 5.3. After recording sketches, participants were asked to explore these actions in a sequence, combining the different movements into a coherent whole.

As previously mentioned, it is beneficial to include participants with some knowledge of how Git works for this bodystorming activity. Therefore, peers and colleagues with experience of working with Git were recruited (in pairs) for the session. I actively participated in these bodystorming sessions, collaborating and exploring ideas with the two participants.

The location of this bodystorming session was not as relevant as in *Spatial workstations*, as there is less need to connect it to the actual workspace. Therefore, one these sessions took place in a regular meeting room at the University of Twente, another in a common space in an office building.

#### 5.3.3 Pilot test

To evaluate the flow of this bodystorming session, I walked through the proposed steps myself. I started with noting down the different actions and 'locations' used for Git version control, and reiterated their meaning. Here I focussed on the five actions that are most commonly used.

After this, I immediately started thinking about how Git using spatial computing could

work. This was not the right approach, as there was no real focus on the individual movements because of this. I immediately wanted to piece everything together and I did not do a lot of exploration of movements. This highlighted the need to first focus on the movements themselves through embodied sketches before piecing it together.

I was also lacking a medium to 'save' my ideas. I believed having a way to store an sketch and later replay it will enhance the willingness to explore new ideas. Following Márquez Segura et al. [45], the best way to save such a sketch seemed to record it on video. To help get a better overview of the videos, I created a simple HTML page to record and save videos using a webcam. This design was further described in the methodology section.

I executed this pilot test in my usual workspace. Because of this, I had the tendency to keep everything centralized around my desk, something that also happened in the pilot I did for the Spatial workstations bodystorm. I expected, since the other sessions will happen in a more neutral space, this would not happen during the other bodystorming sessions.

#### 5.3.4 Findings

Two bodystorming sessions of approximately one hour were conducted with a total of four developers (two in each session), varying in experience and focus (front-end and backend). These sessions followed the same structure. As a co-designer, I actively participated in these sessions, guiding discussion but avoiding overly steering it. Below, I synthesize the key insights from both sessions, organized by theme. A full report of each session can be found in Appendix C.

#### Git actions

**Committing** Participants conceptualized committing in multiple ways, as from the discussions it became apparent that the act of committing has a different interpretation for different people. Some people commit after every major change, while others only commit their changes when they are switching to a different task. Ideas for committing included "imprinting," "putting something aside," or "taking a snapshot." Gestures matching these ideas included placing something on a shelf, flattening or pushing the branch into the desk, or making a locking motion.

**Pushing, pulling and fetching** Pushing was described as a satisfying, conclusive action, "I'm done with this." Movements included throwing a basketball or pushing something upwards into the "cloud." Pulling was imagined as retrieving something from above or afar, with gestures like pulling a rope or reaching overhead. Fetching was differentiated as a broader, more encompassing action, leading to larger gestures like revealing or peeking over barriers. We did notice, however, that these actions were difficult to conceptualize without also thinking about the representations of the branches. These actions gained

meaning through their spatial framing, particularly when imagined in relation to a shared workspace.

**Merging** Initial gestures for merging mimicked putting two things together symmetrically (e.g., pressing hands together), but participants highlighted that Git merges actually happen asymmetrically. Merging was reimagined as inserting or smashing one branch into another.

#### Spatial representation

**Locations and proximity** Different locations were explored where changes in Git are stored (working directory, local repository, remote repository, skipping the staging area since this felt less essential for the workflow). We conceptualized the working directory as something that is closest to the user—on the desk or even on the person themselves. We saw the local repository as a place still in the vicinity of the person, but a bit further away. Here, the code is still only possessed by this person, but a snapshot of it is stored. Finally, we saw the remote repository as something that is further removed from the user, either high up (reflecting the idea of remote content living "in the cloud") or centrally, in a shared location.

**Representing branches** The sessions revealed the difficulty of inventing meaningful gestures without concrete, spatial representations of what those gestures act upon. Despite wanting to steer away from this, the focus naturally shifted from designing skilled movements to developing spatial metaphors and object interactions.

Participants explored several metaphors for representing Git branches, each highlighting different qualities and affordances. One idea, based on having a personal "chain" or necklace that could be moved around, introduced the idea of commit history, with each bead representing an individual commit along a branch. This metaphor captured the linear and sequential nature of development work.

"Threads" hanging from the ceiling offered another take on linearity, emphasizing the idea of branches being suspended and retrievable, although this concept received mixed reactions for being less grounded and harder to interact with. A tree-based structure was also considered, but participants found it less relatable for day-to-day tasks, viewing it primarily as a historical visualization rather than a working model.

Interestingly, physical boxes that were present in one of the spaces where the bodystorms took place emerged as a particularly compelling representation due to their tangibility and versatility. They could be stacked, stored, passed around, or even "merged" by combining them physically, which offered an intuitive and playful way to externalize branch operations.

#### Influences

**Language** Participants' interpretations were significantly shaped by existing Git GUIs and naming conventions. For instance, the metaphors of "pushing" and "pulling" are already embedded in Git's terminology. While these served as helpful starting points, they also constrained the range of imagined interactions. Even tree metaphors, which are common in Git visualization, didn't fully connect with participants—showing that not all standard representations feel meaningful in practice.

**Professional practice** A key insight came from a back-end developer who emphasized the importance of speed and efficiency. While the spatial and embodied approach intrigued him, he stressed that it must ultimately enhance productivity. The potential benefits included improved overviews and reduced abstraction, especially for beginners. However, the design must respect professional workflows and avoid prescribing rigid sequences of actions.

#### 5.3.5 Interpretation and Reflection

The bodystorming sessions for Spatial Git were vibrant and engaging, with participants showing enthusiasm and inspiration throughout. The format revealed new possibilities for embodied and spatial interaction with Git, though it also exposed areas for methodological improvement.

#### Theory versus bodily action

Both sessions began with theoretical framing of the Git actions, which encouraged rich discussion but distracted from the bodily focus intended for bodystorming. Starting with physical warm-ups or immediate engagement in movement could better ground participants in bodily exploration from the outset.

#### Diverse interpretations of computer actions

Participants brought varied understandings of Git concepts such as committing—shaped by their personal workflows. These differences highlight the importance of designing systems that allow for flexibility and personal meaning-making, rather than rigidly defined interactions.

#### Influence of existing interfaces and language

The ideas that were generated were often shaped by existing GUI metaphors and Git terminology. An example of this was the merging of two branches by moving one into another. While these references helped participants ground their ideas, they may also have constrained more original thinking. However, they did serve as useful starting points for reimagining familiar actions in new, embodied ways.

#### Difficulty of actions without representations

The sessions and concepts revealed the difficulty of imagining movement and gestures without some form of visual, spatial, or physical representation of what you are trying to influence. Gestures proved challenging to conceptualize in isolation from the spatial context of the 'code' or 'branch' being affected. As a result, the focus of the sessions shifted toward spatially representing the locations in Git rather than emphasizing the skilled actions themselves. This shift is evident in the design concepts presented, which, in the end, primarily focused on the spatial representation of Git rather than the exploration of skilled actions.

#### Value of tangible props

For the Spatial Git bodystorming session, I had not planned to use any physical props, as the envisioned spatial computing context for the prototype did not include tangible elements. However, there happened to be some cardboard boxes in the room, which participants spontaneously started using during the session. Their presence significantly changed the nature of the exploration. The tangibility of the boxes grounded abstract ideas in physical space and made the session significantly more dynamic.

#### Skilled movement

It remains unclear whether the explored movement qualifies as 'skilled embodied movements' or are simply 'movements.' This raises an intriguing question: is it even possible to 'design' or invent novel skilled movements or interactions? Designing a skilled action implies prescribing how a user should interact with the world, which strongly conflicts with theories of embodied cognition and embodied coping. These theories suggest that appropriate actions are dynamically determined by users based on numerous factors, such as the (social) situatedness [66].

#### Productivity as a requirement

One participant, an experienced back-end developer, emphasized that any new system must enhance efficiency to be considered valuable in a professional setting. While he was intrigued by the spatial approach, he maintained that its usefulness would depend on whether it could accelerate their workflow or reduce friction in daily tasks.

What stands out in his response is the emphasis on a modern, quantifiable notion of value, where productivity, speed, and measurable gains are prioritized. Rather than expressing interest in the system's potential to make work more enjoyable, intuitive, or meaningful, his focus remained firmly on performance metrics. This highlights a common mindset in many professional environments, where efficiency is often seen as the ultimate goal, sometimes at the expense of more qualitative, experiential dimensions of interaction.

#### Reflections on video sticky notes as a tool

The video sticky notes, developed for these bodystorming sessions, provided a useful way to structure the beginning of the bodystorming sessions. However, once recorded, these videos were not used as later reference, contrary to what I expected. I suspect that there are a couple of reasons why this is.

Firstly, the usability of the tool left some to be desired. The website prompted camera access from the browser every time you wanted to record something. Once recorded, the video showed a black preview, only showing the video after clicking the play button. This made it hard to see at a glance all the sketches that were recorded. Furthermore, having a laptop with a webcam was not the ideal form factor for this tool, as it is harder to move around than a handheld device, which sometimes caused difficulty getting everything on video.

Finally, and perhaps most importantly; in the way I currently scaffolded the bodystorming session, there was no logical moment to revisit the recorded videos. In the two bodystorming sessions, I let the bodystorming naturally flow towards a more open exploration where we combined different gestures. This was quite a free and unstructured ordeal, so for me it did not make sense to force the users to revisit all the videos the recorded previously.

#### 5.3.6 Design concepts

Apart from the insights gained, the bodystorming sessions also generated several interesting concepts that can serve as a starting point for design. In this section, I will delve into several of these concepts, elaborating on their potential and illustrating them with sketches to provide a clearer vision of their application.

#### Film roll

One design concept made interesting use of the idea of committing as 'imprinting' or 'stamping' progress on a branches, represented like a film roll. To commit (Figure 5.4), one pushes through their display into a strip, a sort of timeline or film roll, that is displayed behind the main display. This pushes the changes into this strip, marking the change in the timeline. This concept shows a branch as a collection of these imprints into the film roll, making it easy to see the changes over time. To push (Figure 5.5) this branch, one pushes the full film roll upwards, containing all the commits.



Figure 5.4: Committing changes by imprinting the changes on a 'film roll'



Figure 5.5: Pushing changes by pushing the 'film roll' upwards

#### Stack with depth

Another variant of this same concept was similar, but instead of displaying commits as a film roll, it makes use of depth more, with every push adding a new element to a stack. This variant, shown in Figure 5.6 has more emphasis on the fact that every commit builds upon the previous one.



Figure 5.6: Committing changes by imprinting the changes on a 'stack'

#### Necklace

Another concept that was touched upon in both bodystorms was the idea of representing an active branch as a chain or necklace, where beads are added to symbolize changes made in a commit. One participant likened this to a Rosary—a necklace with beads, each representing a step in a prayer ritual. This analogy aligns with the concept of a branch as a sequence of commits. Adding a bead to the chain, which could be worn as a necklace or displayed in another form, would signify a commit to that branch (Figure 5.7). Bringing the entire chain to a storage place would symbolize pushing the branch. While the chain concept is intriguing due to its personal nature, the physical movements associated with committing and pushing do not fully align with the intuitive gestures identified in the bodystorms. Additionally, the idea of a bead emerging from a display feels somewhat artificial and lacks practical coherence. Although this concept offers a visually appealing metaphor, its practical applicability and opportunities for skilled movement appears limited. Furthermore, while this visualisation makes sense for committing and pushing, for merging branches the concept does not hold up.



Figure 5.7: Committing changes by adding a gem to a necklace

Figure 5.8: Pushing changes by bringing necklace to a repository

#### Branch as container

The concept that was explored in most detail, was having a branch as a container. In case of the second bodystorm, a physical cardboard box was used as a physical marker for such a container. Several different locations for the local and remote repositories, as well as for the active directory, were explored. For example; committing changes was explored by either slapping the container (Figure 5.10), or moving the container from the desk (active directory) to the floor (local repository) (Figure 5.9).

The remote repository was conceptualized as a space above the users where the containers can be taken from (checkout, Figure 5.11), or brought to (push, Figure 5.12). However, this remote repository was also conceptualized as an area centrally located at the physical office where all the branches can be seen. This location highlights the remote repository as a shared repository, as its location is not relative to the user, but to the whole group. It also means that the user would have to move more in order to access this location.



Figure 5.9: Committing changes by moving the container from the desk to the floor



Figure 5.11: Checking out a branch by grabbing the container from the remote repository, displayed above the user

# 5.4 Skilled text manipulation



Figure 5.10: Committing changes by slapping the container



Figure 5.12: Pushing changes by moving the container to the remote repository

The goal of this bodystorming session was to explore ways to engage more of the body in everyday computer tasks. In this bodystorm, I focussed specifically on text manipulation, a fundamental aspect of almost every computer-based workflow. With the adoption of computers, we gained a new language for interacting with text: the cursor, the ability to select, delete, and insert text, all actions that were previously impossible. Over time, these actions have become second nature. The objective of this session is to explore how interacting with digital text can be done using skilful interactions.

#### 5.4.1 Methodology

In these bodystorming sessions I took an active role as co-designer, to help probe and develop concepts that go beyond just gestures by applying the theoretical background of this paper. This session followed roughly the same methods as *Spatial Git*. The session started by constructing a list of possible interactions and manipulations with digital text. Following this, the participants explored movements for executing these actions with their whole body using the *video sticky notes* developed for the *Spatial Git* bodystorms. After this initial exploration, we added multiple of these actions into a sequence to explore the flow of these movements. An example of such a sequence would be selecting, copying, and pasting a word.

This bodystorming activity does not require any domain knowledge. Because of this, these bodystorming sessions were done with participants that were not previously involved in the contextual inquiries. The locations for these bodystorming sessions was at the participants' homes.

#### 5.4.2 Pilot test

Because the methods used for this bodystorm session are very similar to *Spatial Git*, and because I aim to actively participate in these bodystorming sessions, I decided to not have a separate pilot test for these bodystorming sessions.

#### 5.4.3 Findings

In total, two bodystorming sessions were conducted, one with three participants and one with two participants (both including the researcher). Each session involved participants with backgrounds in design and human-computer interaction. This section synthesizes the key findings across both sessions. A full report of each session can be found in Appendix D.

#### **Core interactions**

At the heart of the sessions was the question of how common text operations could be reimagined using embodied interaction. Participants began by listing common actions like selecting, cutting, copying, pasting, inserting, removing, and accepting autocorrect suggestions. These served as a foundation for generating and refining gestures.

One of the first insights was that selection need not be a separate action from the main operation. Instead, selecting and performing an action like cutting or copying could be merged into a single fluid movement. This idea led to more seamless and integrated gestures. For example, cutting was imagined as grabbing the selected text and pulling it toward the body, while deleting involved throwing the text away. Pasting became the reverse: retrieving a piece of text from a nearby space and placing it back into the document.

The gesture for copying was harder to conceptualize, as there is no direct real-world equivalent (copying machines exist, but magically copying as a direct action does not). Ideas included stamping motions or sliding a flat hand over the text. The act of selecting itself was often performed by shaping the hand like a bracket and dragging it over the text, which felt more controlled than a pointing motion.

Sound also emerged as an interesting component. Many gestures were accompanied by verbal noises, which appeared to help participants conceptualize the interaction. These vocal cues may suggest that sound could be a part of embodied interaction, offering emphasis or feedback.

Additionally, different participants expressed preferences for distinct gesture styles, with some favouring bigger movements and others leaning toward subtle, precise motions.

#### Dynamic sensitivity

A notable idea that emerged was using depth to control selection precision. I proposed that the distance between the hand and the eyes could act as a sensitivity control: closer movements allow for finer control (e.g., selecting individual characters), while gestures performed further away could select larger areas (e.g., whole paragraphs). This idea evolved into a zoom mechanic, where the virtual page dynamically responds to the spatial position of the user's hand.

This mechanic could introduce a sensorimotor loop that ties vision, body position, and virtual content together. In practice, this could improve text navigation and manipulation, making it more fluid and context-sensitive. For instance, copying a paragraph and pasting it elsewhere could be enhanced by zooming out with a broad gesture and zooming in to refine placement.

#### Storing text

The idea of a temporary storage space emerged while discussing cut and paste actions. Rather than simply moving text from one place to another, participants envisioned a clipboard-like space beside the body. This space could hold cut content temporarily, and potentially even maintain a timeline of previous cuttings for reference. Such a system could enhance user awareness of what's stored and offer new ways of reusing previous content. Deleting followed similar logic: the user would grab and throw away the text. In contrast to cutting, this action involved discarding rather than preserving the text.

#### **Bodily involvement**

During the sessions, I probed the participants to not only think about using their hands, but to use their full body in interaction. While hands and arms naturally lent themselves to precise, intentional movements, the legs were harder to integrate. Some interactions, like

a kicking motion for deleting, felt expressive but also fatiguing and less suited for frequent use.

#### 5.4.4 Interpretation and reflection

Compared to previous bodystorms, such as those conducted for *Spatial Git*, there was noticeably less verbal discussion about the movements in this exploration, especially in the first session. Many gestures appeared to arise instinctively rather than through theoretical reasoning. Some movements simply "felt right," indicating that this session leaned more toward exploring the inherent physicality of interactions rather than dissecting their theoretical meaning.

During the second session, we reflected on how a movement-based or spatial interaction system might initially slow down work, but could ultimately prove beneficial in the long run. We drew a comparison to handwriting: while it is slower than typing, it also has advantages, such as increased cognitive engagement and memory retention. Similarly, embodied interactions may foster a deeper sense of engagement with digital content, though only if they are perceived as effective.

Similar to the findings of the Spatial Git bodystorm, it remains a question whether the gestures that were designed would actually add meaningful skill to interaction with digital text. However, the dynamic movement that would map the sensitivity of a gesture to the distance of the gesture to the body, seems promising. Because of the dynamic link between these elements, there seems an opportunity for embody skill to emerge.

#### 5.4.5 Design concepts

From the bodystorming sessions, there was one concept that stood out as being a potentially 'skilful' interaction based on the realization that selecting text and performing an associated action, such as copying or cutting, do not need to be separate steps. By eliminating the distinction between these steps, users could interact with text in a way that mirrors natural physical interactions.

One of the primary challenges we found, was that in gesture-based text selection is ensuring precision across different levels of scale, such as selecting individual characters, entire words, or whole paragraphs. A proposed solution to this challenge was to map the relationship between hand position and perceived motion speed. When the hand is positioned closer to the user's eyes, movement relative to the background appears faster, allowing for fine-grained control over smaller areas of text. When the hand is positioned farther away, motion appears slower and more sweeping, enabling the selection of larger text segments.

This principle led to the development of a mechanic where the hand's distance from the user dynamically influences the zoom level of the virtual document. By tying zoom control to hand movement, users can continuously transition between detailed and broad views of text, creating an immersive sensorimotor loop. It introduces a balance between precision and speed, similar to what I observed in the contextual inquiries: zooming in for detail-oriented tasks and zooming out for broader context.

# 5.5 Reflection on iteration 2

While each bodystorming session in this iteration was centred around a distinct design concept, reflecting on them reveals valuable findings beyond their surface-level objectives.

#### Challenges of co-designing in familiar contexts

In all bodystorming sessions, I employed a form of co-design. However, as I already mentioned previously, co-exploring novel ideas that are closely tied to participants' daily lives and experiences presents significant challenges. Because participants are familiar with existing digital work environments, their expectations and habits are shaped by these conventions. As a result, introducing radically new spatial computing concepts without a direct reference to familiar paradigms was difficult. I believe we have grown so accustomed to how computers currently work, that it is hard for people to break out of this way of thinking, even (or maybe even especially) for non-designers.

#### Translation of computer tasks into human tasks

With this study focussing on skilled actions, I started the bodystorming sessions from the perspective of computer actions. The approach of taking computer actions and translating them to human actions contained an inherent contradiction. For example, for *Skilled text manipulation*, The actions we aimed to redesign, such as selecting, copying, and pasting, are not inherently human gestures but rather behaviours that exist because of how computers structure text interaction. In attempting to rethink these actions in a spatial context, we were still anchored to the very paradigms I aimed to move beyond.

#### Can skill be 'designed'?

The sessions, especially *Spatial Git* and *Skilled text manipulation*, raised a fundamental question: is it possible design for skilled interaction? While many concepts encouraged more movement, it remains uncertain whether this movement would lead to or require true skill development. Simply increasing bodily engagement does not guarantee the emergence of skill.

# 5.6 Conclusion

Through this iteration of the research, I developed a deeper understanding of what it truly means for a designer to design for skill. Fostering embodied skills may require moving beyond traditional interaction design techniques, which often rely on predefined gestures or movements to trigger specific system actions. Instead, designing for skill should focus on setting the stage where interactions emerge naturally through (socio)sensorimotor loops.

In the next iteration of this process, I will develop one of these concepts further into a prototype. Among the various concepts explored, the most promising ones were the 'spatialisation' of branches in *Spatial Git* and the dynamic movement of text editing actions and page zoom level in *Skilled text manipulation*. From these two, *Spatial Git* made most use of the possibilities unlocked by spatial computing in particular. Therefore, I have selected *Spatial Git* to explore further in the third iteration.

# Chapter 6 Third Iteration, Design

In this chapter, I will develop the concept of *Spatial Git* further to move from theoretical exploration toward a concrete, interactive prototype. The following section will present a design frame that combines previous findings and the underlying theory. Next, I will describe the ideation process and results based on this frame. Finally, I will describe the technical implementation of the prototype.

# 6.1 Design frame

The goal of this design is to explore and illustrate how spatial computing can present a way to involve more of our embodied skills in our interaction with technology, illustrated by this specific case of interacting with Git version control. In this section, I will frame the design using the findings from the previous iterations of my research, combined with the theoretical background.

The subject of Git first appeared on the radar during the contextual inquiries with developers in the first iteration of the research. Here, developers mentioned how Git is an essential part of their workflow. Several developers also mentioned that Git is quite an abstract tool, which is hard to get into for new developers. Originally, the main way of interacting with Git was via a command line interface (Figure 6.1a), however nowadays in most modern coding tools (integrated development environments (IDEs)), Git tools are displayed using a GUI (Figure 6.1b).

There are several key considerations, either from the previous iterations, the background or objectives that I take with me into the design phase. Because this design serves as an exploration of the opportunities of spatial computing, the focus of the design should be making use of space and the environment in which the user finds themself. This means considering how users move through their environment, how digital elements interact with physical space, and how the location of the interactions can carry meaning. Additionally, I take inspiration from the craftsperson's studio as a way to rethink office spaces. By embrac-



(a) Git UI via the command line [10]



Figure 6.1: Comparison of Git interfaces used in development environments

ing the principles of a workshop-like environment, where materials and works-in-progress are meaningfully arranged in physical space, I aim to explore how spatial computing can make office work more tangible, intuitive, and engaging.

In addition, the focus on embodied skills means that we should design in consideration of sensorimotor couplings. This requires acknowledging how perception, action, and social context are intertwined in shaping user interactions. Instead of treating input and output as separate processes, the design should support fluid, real-time feedback that aligns with natural movements and behaviours.

During the bodystorming sessions, we worked from a set of Git actions and explored gestural representations for these actions. There I already discussed how these actions could have different personal meanings. These actions affect a code branch, which could be seen as a copy of the main code. These copies can be stored in one of three locations; in the remote repository (on a remote server), the local repository (on one's local device), and the active directory, which means that one is actively working on the code.

The challenge for the system is that these branches and locations should designed in such a way that the movement that is used for carrying out the actions holds inherent meaning. In addition, it is important to consider that these actions are not done in isolation, they fit into a workflow. In order to better get an idea of these workflows using Git, I have created two scenarios.

#### Sarah

Sarah is starting work on a new feature for her team's shared project. To begin her work, she first clones the project repository from the company's remote repository onto her local machine, ensuring she has the latest version of the codebase to work with.

Before making any changes, Sarah creates and checks out a new branch specifically for her feature. This keeps her work separate from the main branch, allowing her to experiment and develop the feature without affecting the stable version of the project. Over the course of a few hours, Sarah writes the necessary code and periodically commits her changes to her local branch, making sure to write meaningful commit messages that describe her updates. Committing frequently helps her track progress and makes it easier to revert changes if necessary.

Since the project is collaborative, Sarah wants to ensure her branch is up to date with any changes her teammates might have pushed. She pulls the latest changes from the main branch into her local branch, resolving a minor merge conflict along the way. This step prevents potential integration issues later.

Once she is satisfied with her work and has tested the new feature, Sarah pushes her branch to the remote repository. She then opens a pull request so her teammates can review her code before merging it into the main branch.

#### Jack

At the start of his day, Jack is working on a new feature. Suddenly, his team lead pings him, asking him to fix an urgent bug. Since this bug is unrelated to his current task, Jack switches to his local version of the main branch to get a stable version of the project. Before proceeding, he pulls the latest changes from the main branch to ensure he is working with the most up-to-date code.

Next, Jack needs to check out a branch that his teammate created earlier for the bug fix. He does not have it locally yet, so he fetches the latest branches from the remote repository and then checks out the branch to start working on it. He makes the necessary changes to fix the bug and then commits his updates with a clear message. Since this is an urgent fix, he immediately pushes the branch to the remote repository and creates a pull request for the team to review.

Once that task is completed, Jack returns to his primary work. He switches back to his previous branch to continue developing. Before making further changes, he decides to sync his branch with any recent updates, so he rebases his branch onto the latest main branch. This ensures he's working with the most recent improvements and avoids integration issues later.

After coding for a while and testing his changes, Jack commits his latest updates. At the end of the day, his branch is not finished yet but he wants to back up his work, so he pushes his branch to the remote repository so his progress is stored and accessible to his team.

# 6.2 Design and concept sketches

#### 6.2.1 Repository locations

Following the reasoning on how Git works from the bodystorm sessions, I defined that the remote repository, the local repository and working directory are three separate locations where branches of code 'can be stored'. Several ideas were generated during the bodystorming sessions about what these locations could be. To illustrate and explore these ideas, I made some simple sketches highlighting these different locations. In these sketches, a yellow area means the remote repository, the orange area means the working directory and the red area means the local repository.

**Desk-floor-ceiling** (Figure 6.2). One of the concepts that were explored was having the remote repository above the user on the ceiling, which aligns with our mental model of a remote location being 'in the cloud'. The working directory would be on the desk in this concept, and the local repository would be on the floor under the desk. Having the branch present on the desk signifies this branch as the work in progress. One downside of this concept is that it still centred around the desk and does not make use of the physical space beyond the desk.

**Desk-floor-central location** (Figure 6.3). An evolution of the previous concept would be having the remote repository be a shared, central location within the office, where one would need to go to to check out or push a branch. This stimulates movement and strengthens the idea that the remote repository is a shared repository.



Figure 6.2: Desk-floor-ceiling



Figure 6.3: Desk-floor-central location

**Central location - local location** (Figure 6.4). One could reason that the working directory is just a branch from the local repository that is actively being worked on. Following this logic, the there does not necessarily have to be a separate location for this. Instead, this branch could live in the same location as the other local branches, but be visually signified as the active branch.



Figure 6.4: Central location - local location

#### 6.2.2 Branch representation

The next design challenge involves determining an appropriate representation for the branches. It is important to note that the goal is not merely to represent digital content (the branches), but to use this representation as a scaffolding for the socially situated use of the (digital) artifact. The design should facilitate the formation of sensorimotor couplings, enabling users to intuitively engage with the system.

Functionally, the representation of branches needs to enable the user to differentiate between branches, provide a movable token or container to move between the different zones, and to allow the user to add commits and see previous commits on the branch. This differentiation could be achieved by displaying the names of the branches be present on the container objects. There does not seem to be any practical, straightforward alternative for using text in this case. Additionally, incorporating size as a meaningful attribute to the container could enhance the design. Larger containers could signify branches with more changes. This would make work-in-progress more visible within the workspace, potentially supporting collaboration between developers.

What was most compelling during the bodystorming sessions was how an incidental object, a box that was present in the room, emerged as a surprisingly effective scaffold for exploring new interaction possibilities. This unexpected discovery opened up new ways of thinking about the design. Based on this, one possibility is making the 'container object' an abstract shape to help in this design being supportive of personal meaning making.

What is missing in this representation is that a branch contains a series of commits. While this does not necessarily have to be a problem, as you do not need to see all the previous commits at any time, it does perhaps make it visually unclear how you would add a commit to the branch. An alternative representation could be visualizing branches


Figure 6.5: Branches as abstract container objects, in three different locations

as a chain or even as a necklace, as was mentioned in the previous iteration. In this way, previous commits could be displayed like nodes on this chain. Branches with more commits show more nodes, while the space between the nodes could give the user an idea about either the time between each commit (turning the chain into a timeline), or the amount of lines of code change between each commit, giving an idea about the impact of each commit. In the sketch in Figure 6.6, I visualized the branch that actively is being worked on as coming out of the computer monitor. As one is making more changes to the file, this branch could grow longer.



Figure 6.6: Branches as chains with commits visualized as nodes on the chain. Here, the branches are visualized in two locations, a remote repository, a local repository, which contains the branch that is actively being worked on.

Other, more metaphorical representations were also considered, such as an actual tree



Figure 6.7: Git branches visualized as actual tree branches.

branch. This does a good job visualising the dependencies of branches. It shows how the branches relate to each other, as can be seen in Figure 6.7. However, in the discussions with the developers during the bodystorm, I learned that in daily operation this tree model is not really part of how the developers I spoke to experience working with Git.

Because the design consisting of a chain of nodes as described in Figure 6.6 contains the most utility, as you are immediately able to see previous commits on a branch and the size of the branch, this concept was selected as the most promising.

#### 6.2.3 Actions

During the bodystorming sessions we already explored, from a physical perspective, what movements would 'feel right' or 'make sense' for acting in Git. In that exploration, we initially did not consider the representations of the subject of these interactions. While these representations are not the focus, they are important in forming the sensorimotor couplings that shape our actions. We determine what appropriate action is based on this sensorimotor coupling. Now that we have determined a 'physical' shape and the locations for the branches and repositories, we can further explore the actions to interact with them.

#### Check out

Checking out a branch was only discussed as an action during the second bodystorming session, but is quite an essential part of using Git. At that stage in the session, we had already decided that a branch should be a container, and it was ideated that checking out a branch was grabbing it from the remote repository and bringing it to the desk. With the visualisation of the branches as a growing chain of nodes coming out of the computer, the

branch should be brought the top of the computer screen. Perhaps to make it clearer that a branch can be attached to this display, there should be some visual marker. Checking out a branch from the local repository works similarly, one grabs the branch from somewhere close to them and moves it to the attachment point.

An important nuance in this action is that the checked out branch should not disappear from the remote repository. Checking a branch out does not mean it is removed from the remote repository any more. Therefore, grabbing a branch should create a copied instance of that branch that can be taken towards the attachment point.

#### New branch

Creating a new branch is always done based on an existing branch, except if it is the first branch in the repository. It is as if making a copy of another branch. During the bodystorm sessions, there were several ideas for creating a new branch, but these ideas all imagined creating a new branch from thin air, not as branch of another branch.

Where checking out a branch means creating a copied instance of a branch that still refers to the original branch to the local repository, creating a new branch creates a split off of that branch. Therefore, a two-handed splitting motion on that branch seems like a logical movement.

#### Commit

Each commit is represented as a node or 'milestone' on the branch, meaning that committing changes adds a new node to the chain. During bodystorming sessions, we explored how the motion for committing should be more subtle and fluid than pushing. We considered gestures like slapping a container to create a snapshot or pushing forward to imprint a change. The action should feel decisive yet natural, allowing the user to stay in the flow.

With the branch extending from the active window and growing as changes are made, committing should feel like cinching off a section of the branch. A possible interaction is gripping the branch at its attachment point on the screen, effectively sealing off that part as a committed node. This attachment point should be designed as an 'not-cinched' state of the node, visually reinforcing the commit action.

#### Push

During the first bodystorm session, where we did not explore the location-based concept, the action of pushing was done with various types of pushing motions, inspired by the language used to describe the action. However, in the second bodystorm session, pushing the code by bringing the branch to the remote repository was introduced, which made immediate sense. The movement should be the reverse of checking out a branch; again it

should be a copy of the branch that should be brought to the remote repository location, since the branch will not be removed from the local repository if it is pushed.

#### Pull and fetch

The final missing link is fetching and pulling branches. Fetching can be seen as a reload of the local repository to see if anyone pushed any changes to the branches one has checked out. Pulling is similar, but it it combines this fetching action with adding changes to the local branch one is pulling on.

Since fetching is a passive action that could happen automatically when looking at the remote branches, it should require no additional gesture from the user. Perhaps a simple gaze towards the branches could be enough to trigger the fetching action. However, pulling is an active choice to integrate new changes into the local branch and should be reflected in a deliberate action.

A natural way to represent pulling is through a movement that reinforces the idea of retrieving updates and merging them into the local workspace. One possibility is a 'tugging' gesture on the branch while it is attached to the local workspace, visually drawing in the latest changes from the remote. This gesture emphasizes the continuity of the branch while incorporating the updates. The branch should visibly respond to this action, showing the integration of new nodes.

#### 6.2.4 Final concept sketches

In the following section I will describe the envisioned interactions in detail, supported by sketches that illustrate how each action might appear in the AR interface.

## Checking out a branch



Figure 6.8: Checking out a branch

The developer is working on a feature located in the *login* branch, which exists in the remote repository. They walk up to the area where the remote repositories are displayed, and grab the *login* branch. As the developer grabs the branch, his copy of the branch becomes slightly translucent to show that it is a instance of the branch that is stored in the repository. The developer brings the branch to their workstation and attaches it to the attachment point above the screen. This loads in the code on their computer, ready to be worked on.

#### **Sketch description:**

1: Central area with the branches in the remote repository. 2: Grabbing a branch, the original branch stays in place, the branch in hand becomes translucent. 3: Placing the branch onto the attachment point. 4: the branch is now in the working directory, ready to be edited. (Figure 6.8)

## Creating a new branch



Figure 6.9: Creating a new branch

After reviewing the *login* branch, the developer decides to create a new branch based on it for additional modifications called *login-enhancements*. They grab the bottom node of *login* branch and splits it off from the branch. This causes a new virtual branch to form from the node after it is reattached to the mounting point.

#### **Sketch description:**

1: Grabbing the active branch (or a branch from the remote repository location). 2: Splitting off the latest node from the original branch. 3: Reattaching this to the attachment point. (Figure 6.9)

## **Committing changes**



Figure 6.10: Committing changes

The developer makes several changes to the code, and as they work, the branch begins to grow. When they're satisfied with their progress, they decide to commit the changes. They grip the attachment point of the branch and "cinch" it, as if sealing off the section of the branch containing their recent changes. The branch's attachment point reacts by visually tightening, locking the changes in place and adding a node to the chain.

#### **Sketch description:**

1: Reaching towards the attachment point. 2: Grabbing the attachment point and pinching it with the full hand. 3: Write a commit message using keyboard. 4: This message is automatically added to the commit node, for later reference. (Figure 6.10)

### Pushing the changes



Figure 6.11: Pushing the changes

The developer decides to push their changes to the remote repository. They reach for the *login-enhancements* branch and grab onto it. The branch in the hand becomes slightly translucent while the original branch stays in place, reinforcing the idea that this is a copy of the branch, not a removal from the local repository. The developer heads with the branch to the shared location, completing the push to the remote repository.

#### **Sketch description:**

1: Pulling on the branch to remove it from the attachment point. 2: Grabbing the branch, while the original branch stays in place. The branch in the hand becomes translucent and a commit node is added to the bottom, to ensure no local changes are lost (akin to the 'commit and push' feature in many IDEs). 3: The branch is brought to the remote repository where it will be displayed (Figure 6.11)

## Fetching updates



Figure 6.12: Fetching updates

While working on their local branch, the developer occasionally glances at the remote repository, where other branches are displayed. Fetching happens automatically, updating the local view to reflect any new changes that have been pushed to remote branches they have checked out. No additional gesture is required for this action, it is integrated into the workflow, providing the latest updates without interrupting the developer's work.

#### **Sketch description:**

1: The developer is working on their branch, only viewing the active branch with the other local branches being present remotely. 2: The developer views the remote branches, which fetches the changes, showing that there are new commits to the remote branches. (Figure 6.12)

## Updating the branch



Figure 6.13: Updating the branch

After a few moments of reviewing the code, the developer notices that another collaborator has pushed updates to the *login* branch. They decide to pull the latest changes by performing a tugging motion on the branch. The branch visually responds to the pull, with new nodes merging into the local branch. The updates are now part of the local workspace, and the branch is ready for further development.

#### **Sketch description:**

1: New commits to the local or active branch are shown by a translucent extension of the branch through the attachment point. 2: The developer grabs and pulls up the branch to update the branch with the latest commits. 3:The branch is now up to date. (Figure 6.13)

### 6.3 Technical implementation

To further illustrate this concept and to allow me to explore and evaluate the concept with users, I developed an interactive prototype. Due to a limited amount of time I focussed on enabling the most important envisioned interactions, instead of making a fully-functional prototype that actually uses Git and is connected to an IDE.

The hardware used for the prototype is the Meta Quest 3 VR headset. This was chosen because of its acceptable pass-through mode to enable mixed reality experiences, and its robust SDK. Other options were also considered, such as Apple Vision Pro or Microsoft Hololens, but these were dismissed due to practicality reasons. The Apple Vision Pro is not widely available in the Netherlands while the Hololens has fewer capabilities for making digital contents interact with real-world elements .

The interactive prototype was developed using Unity paired with the Meta XR SDK. Branches were randomly generated and had placeholder names. These branches had a random amount of nodes that were at random distances from each other. Using a scene manager component, these branches were spawned in specific locations in the office. While the aim was to only have the branches spawn above a central area, I was not able to replicate this with precision. Instead, I manually moved the branches towards this central area before starting an evaluation session.

#### 6.3.1 Limitations and concessions

Due to time and resource constraints, I made several concessions during the development of this prototype. As mentioned earlier, the prototype does not connect to an actual Git repository. Instead, branches are generated randomly with arbitrary names.

Another limitation is the range of possible actions. Some envisioned actions required more complex scripting than others. The prototype includes checking out a branch, committing changes, and pulling updates. Committing, however, is implemented differently than initially designed: instead of grabbing the mounting point, users must quickly remove and reattach the branch. Actions such as creating a new branch, fetching updates, and updating an existing branch were not included in the prototype.

Finally, certain visual details that aid communication were omitted. For example, to emphasize that checking out a branch from the remote repository creates a copy rather than removing the original, I had planned for the original branch to remain in place while a translucent copy was moved. This detail was not implemented; instead, the entire branch moves when grabbed.

#### 6.3.2 Prototype images

Figure 6.14 to 6.19 display the interactions with the prototype as created in Unity. A demo of the system can be seen via the following link: https://bit.ly/spatialgit





Figure 6.14





Figure 6.16



Figure 6.17



Figure 6.18





Figure 6.14 displays a single branch, consisting of commits as nodes, and a label with the branch number and name underneath.

In Figure 6.15, you see the branches in the local repository, close to the display. At the bottom of the image you see the mounting point of the computer screen.

In Figure 6.16, you see a branch that is actively being worked on. The commit nodes become a different colour and the branch label is hidden. The branch is growing from a translucent node showing that this is a starting point.

In Figure 6.17 you see how a brand is committed by removing it from the mounting point. The branch label reappears and the translucent sphere is now a solid sphere, showing that the changes are committed.

In Figure 6.18, you see how the branch can be moved by grabbing onto it and moving it to another location.

In Figure 6.19, you see several branches stored in the remote location.

# Chapter 7 Evaluation

Rather than assessing the prototype as a finished product, this evaluation presents it as a design probe to stimulate discussion and reflection. By engaging with the prototype, participants are encouraged to consider how spatial interaction might bring more skilful engagement into their workflow, shifting away from traditionally sedentary practices.

Additionally, the evaluation seeks to understand whether and how this prototype could support users' feelings of craftsmanship. Finally, I aim to investigate the potential impact of spatial embodied interactions on the way developers work and collaborate, questioning how spatial representations of version control might influence cognitive processes, problem-solving strategies, and team dynamics, and ultimately might shape a certain 'studio practice'.

#### 7.1 Methodology

The prototype was evaluated with seven people from the potential end-user group. These are a mix of front-end and back-end developers across one organisation. Three of them were included were also part of the bodystorming sessions and thus were already more aware of this research. Within this group there was a mix of seniorities, which gave several perspectives on the prototype.

The interaction with the prototype took place in the participants' office and took between 7 and 23 minutes (13 minutes average, two under 10 minutes). Before starting the evaluation, the participants were briefed and signed informed consent forms (Under the same conditions and application number 240793 as mentioned in Section 1.0.2).

To introduce the concept and the capabilities of the prototype, I first demonstrated its use. Participants could follow my perspective in real time, as the Meta Quest display was cast to a screen. I explained the limitations of the system clearly. Following this demonstration, they were invited to explore the prototype themselves. I could see what the participants were doing via this same casting feature. After interacting with the prototype, I facilitated an open-ended discussion about their experience. This discussion was structured into three phases. First, we discussed how the prototype might alter the way their body is engaged in their work. Next, we discussed how it aligns with their professional identity and whether it supports craftsmanship-as-a-practice. Finally, I asked them to reflect on how this technology could influence collaboration within a 'studio' setting. A list of questions asked during the evaluation can be found in Appendix E.

### 7.2 Findings

#### 7.2.1 General findings

The overall reception of the *Spatial Git* prototype was mixed. While participants saw clear advantages in terms of team collaboration, project visibility, and organization, they were less convinced about its impact on their feelings of craftsmanship, or the presence of physical skills. Three participants stated that they did not feel constrained by their current Git workflows and questioned whether this system would provide a meaningful improvement over existing tools.

#### Concept clear despite technical limitations

Despite the prototype being a non-functional proof of concept, its usability was sufficient to give participants a clear and immediate understanding of the concept. Most participants quickly grasped the intended interactions and had little difficulty engaging with the system.

However, a common critique across multiple participants was that current hardware limitations make it impractical for everyday use. The weight of the device and the lowquality image pass-through were seen as significant obstacles, with some developers stating that they would not want to wear the headset for extended periods.

#### Potential beyond version control

A particularly interesting finding was that the system seemed to offer more value for project and task management than for version control itself. Several participants noted that the ability to spatially arrange and visualize branches could improve task organization and prioritization, especially when combined with task management systems. This opens up potential for the system to be used in broader work coordination contexts rather than just for managing Git repositories.

#### Potential educational use for beginners

Two participants suggested that the system might be useful for junior developers, as it could make Git concepts more visually understandable. One back-end developer noted that the system could help beginners grasp Git faster because it externalizes the otherwise abstract nature of branches and versioning. However, this observation contradicts the original research goal, which was not to simplify Git but rather to explore new interaction paradigms that would require skill.

#### 7.2.2 Bodily engagement and physical skills

#### Minimal gains in movement

The system was met with mixed responses regarding bodily engagement and the requirement for physical skills. Some participants appreciated that the system required occasional movement, which they felt could be beneficial in their workflow. One developer noted that the system encouraged more natural movement than other workplace interventions, such as standing desks. However, others believed that the level of movement required was minimal and would not significantly impact their daily routine, since the act of checking out and pushing branches is not something that is done very frequently.

#### Lack of skill-based interaction

There was also scepticism about whether the system involved any meaningful physical skill. Several developers pointed out that interacting with branches did not require any skill or learning curve beyond basic usage and they did not view their ability to interact with the system as something that could improve over time. One participant suggested that introducing more dynamic interactions such as flicking, throwing, or skill-based gestures could create a sense of skill. Without these elements, however, none of the developers perceived the system as requiring or fostering physical skill.

#### 7.2.3 Impact on craftsmanship-as-a-practice

#### No perceived contribution to professional identity

The evaluation found that the developers think the *Spatial Git* system would not significantly contribute to their professional identity as a developer. When asked whether the system would make them better developers, four participants explicitly stated that they believed it would not.

Despite this, some developers appreciated the tangible nature of the system, as it made work more visible and organized. A front-end developer mentioned that the system could make work more enjoyable, but enjoyment does not necessarily equate to craftsmanship. Two developers noted that it provides a better sense of project organization, which might indirectly support craftsmanship by encouraging better workflow discipline. However, this benefit was more related to project management than to the craft of software development itself.

#### Seen as helpful for collaboration but not for coding

While the system was seen as beneficial for collaboration, it was not perceived as something that could enhance the craft of software development itself. Developers emphasized that their craft is centred around writing code and solving problems, and *Spatial Git* would not improve their ability to do so. Some participants, particularly those with extensive experience, saw little advantage over conventional Git workflows and did not believe the system added value to their technical expertise.

#### 7.2.4 Collaboration and team dynamics

#### Visualising works-in-progress

The Spatial Git system was largely seen as a tool that could enhance collaboration and team dynamics by providing greater visibility into work-in-progress. Several participants noted that one of its biggest strengths was the ability to see what colleagues are working on without needing to ask them directly. This feature was particularly appreciated by team leaders overseeing multiple developers, as it allows them to quickly assess project progress and identify who was responsible for which branch.

By observing the spatial layout of branches, they imagined how they could quickly glance which features or fixes were in progress, who was working on them, and how many changes had been made. This kind of immediate visibility was noted as being more intuitive and fluid than traditional dashboards or project management tools

However, the impact on direct communication within teams was debated. While some felt that having a visual representation of active work could streamline discussions, others worried that it might actually reduce direct interaction between colleagues. If developers no longer needed to ask what someone was working on because they could simply see it, this might limit spontaneous discussions and collaborative problem-solving moments.

#### Supporting task delegation and review

Another positive aspect mentioned was that the system could make code reviews and task delegation more fluid. In one instance, a developer physically handed a branch to a colleague and asked for a review, which sparked a conversation about how the system could support structuring code review processes in a more intuitive way. This type of interaction,

where tasks are naturally exchanged through physical movement, was seen as a potential improvement over traditional, more abstract digital task management systems such as GitHub, Gitea or Jira.

#### Not useful for all working styles

Some developers expressed scepticism about the system's necessity for their own work. An experienced back-end developer mentioned that because they often work independently, they do not rely on external tools to keep track of what others are doing. For them, a simple notebook was sufficient for task management, and they did not see an advantage in having a shared spatial overview.

#### Scalability concerns

Some participants raised concerns about how the system would handle a large number of branches. In larger teams with frequent branching, the spatial representation could become cluttered and difficult to navigate. One developer suggested implementing a system of filters or grouping mechanisms, such as arranging branches by type. Another developer proposed a tree-based visualization rather than independent branches, which could better illustrate the relationships between branches.

#### Micromanagement concerns

Another concern raised was the potential for micromanagement. Some participants pointed out that if a manager could easily see what everyone was working on at all times, it might lead to increased scrutiny rather than fostering trust-based collaboration. This risk aligns with how through modernist management styles, work has become much more quantifiable at the expense of personal autonomy (which I mentioned in Section 2.0.1).

#### Highlighting neglected branches

Another notable observation was that the system helped to visualize neglected or stale branches. Several developers mentioned that in traditional Git workflows, inactive branches tend to accumulate and are often forgotten. By making them physically present in the workspace, the system could encourage better branch management and reduce repository clutter over time.

#### 7.3 Conclusion

This evaluation highlights both the promise and the limitations of the *Spatial Git* prototype. While the system presented several advantages of using spatial computing for Git, it fell

short of fundamentally reshaping participants' sense of craftsmanship or physical skill. Its potential was most strongly felt in the domains of team coordination, project visibility, and task management.

Crucially, the evaluation revealed that the strength of the prototype lies not in replacing existing Git workflows but in reframing how digital collaborative work is made visible, organized, and shared. This opens up interesting opportunities for future design directions that further explore spatial representations as tools for coordination.

## Chapter 8 Discussion

Given its exploratory nature and research-through-design approach, the insights gained throughout the process of this study are just as valuable (if not more) as the final artifact produced. In the following section, I will discuss the most significant insights of this RtD process, their broader implications, and their relation to existing literature.

The section concludes with a critical reflection on the limitations of the study, including methodological considerations and the scope of participant engagement. It also presents recommendations for future research that could further investigate or expand on the ideas presented here.

#### 8.1 Reflection

#### 8.1.1 On the design process

#### Balancing theoretical design principles and real-world practice

Key insights from the bodystorming sessions on *Spatial workstations* revealed that transitioning from the familiar 2D paradigm to spatial computing posed a challenge for some participants. While some embraced the concept, others clung to the conventional 2D desktop metaphor, arranging all their tools on a single wall. This suggests that office workers are so accustomed to this paradigm that it has become second nature.

Part of this behaviour may have been caused by the setup of the bodystorming session itself. By asking participants to create paper sheets with application names, I may have reinforced the idea of applications as 2D windows. However, it also highlights the difficulty of involving (potential) end-users in the design process of new paradigms. Pushing too far beyond familiar ground can leave participants unable to engage meaningfully, while staying too close to what they know can limit the emergence of new ideas.

The decision to design within the reality of today's technology and work environments also meant that I, as a designer, was more limited in exploring the range of possibilities of embodied skill using spatial computing. In different contexts, similar interactive technologies are certainly capable of allowing for embodied skill development. VR games like Beat Saber demonstrate this. However, applying this concept to office work is more difficult. Many modern jobs have become increasingly abstract, theoretical, and disembodied. Addressing this shift meaningfully requires more than just adding physical interaction; it demands a fundamental reconsideration of how work and technology intersect with human movement and skill.

This tension also influences how the prototype is evaluated. Because it closely engages with the day-to-day realities of office professionals, participants' feedback was often shaped by short-term concerns and immediate impact on workflows. One comment that was mentioned often in the evaluation, for example, were the current shortcomings of the hardware. In contrast, more abstract or speculative concepts, being further removed from current practice, could be easier to imagine as part of a possible future.

#### Can you design skilled action?

One of the primary challenges I encountered during this research was the difficulty of designing truly skilful interactions. Although my aim was to introduce skilled movement into office work, I can conclude that I did not succeed in exploring genuinely meaningful skilful interactions.

As Djajadiningrat et al. [13] already point out, designing for skilful movement is significantly constrained when using interactive technologies such as mixed reality. The complexity of the physical world, essential for developing rich sensorimotor couplings, is difficult to replicate digitally. Traditional computer interfaces, while limited, still provide some haptic feedback, like the resistance of keys or the friction of a mouse. In mixed reality, these tactile cues are largely absent, unless supplemented with physical props or controllers. This absence may also explain why theories of embodied cognition have been more successfully applied in hybrid technologies [67], which preserve a connection to the tangible physical world.

This challenge was already apparent during the bodystorming sessions for both *Spatial Git* and *Skilled text manipulation*. While these sessions did encourage movement, the movement itself lacked truly skilled interaction. This raised a deeper question: can skilful interaction be intentionally designed, or must it instead emerge over time?

Embodied theories state that skills emerge through use, as a set of 'attunements' to react to perceptions of the current situation [16]. Attempting to 'invent' a new skill in isolation seems inherently difficult, if not impossible. Instead of prescribing specific movements, it may be more fruitful to design environments and tools that foster the potential for skill to emerge. The real challenge lies in creating conditions that support open-ended exploration and the gradual development of sensorimotor loops, rather than in specifying

skilful interaction from the outset.

There was, however, one concept that emerged during the bodystorming sessions which showed potential for fostering a sensorimotor loop. This was the idea of dynamically mapping selection sensitivity to the distance from the body at which it is performed, in the bodystorm for *Skilled text manipulation*. This mechanism seemed to possess some of the fluid, responsive qualities characteristic of skilled action. Interestingly, it did not arise directly from bodily exploration, but rather from theoretical reasoning. This suggests that while bodily exploration can inspire ideas, some aspects of designing for skilled action may also benefit from reflective design thinking though the lens of embodied interaction.

#### Computer actions are not human actions

A key shortcoming of the bodystorming sessions was my attempt to directly map computer actions onto human ones. While computers operate through discrete, predefined commands, human actions are fluid, context-sensitive, and adaptive. Forcing a one-to-one translation overlooks the richness and subtlety of embodied coping. Rather than mimicking computer functions, a better approach would be to explore how embodied actions naturally evolve, and how technology might support that evolution, rather than prescribe it.

This issue is not unique to my own process; it reflects a broader limitation within the field of interaction design. Many conventional methods of interaction rely on predefined gestures or symbolic mappings, which can unintentionally reinforce a Cognitivist view that separates internal cognition from external action [66]. If we want to foster embodied skills, we may need to move beyond these design paradigms. Designing for skill is less about defining specific movements and more about creating environments in which meaningful sensorimotor couplings can emerge organically over time.

## Video sticky notes could aid in dealing with the ephemeral nature of embodied sketching

The video sticky notes were developed as a simple digital tool to capture movement 'sketches' during bodystorming sessions. They enabled participants to record short clips of gestures or movement sequences, with the intention of creating a browsable archive of physical sketches. While they proved helpful for initiating sessions, these recordings were not actively revisited during or after the sessions, contrary to their intended purpose.

Several limitations contributed to this outcome. The tool had several usability issues, such as repeated prompts for camera access, unclear video previews, and limited mobility due to its use on a laptop. More importantly, the structure of the bodystorming sessions did not include a natural point at which to review prior recordings. As a result, the video sticky notes functioned more as short-term scaffolding than as a lasting reference.

The video sticky notes can be seen as an attempt to address a clear challenge also recognized in the original Márquez Segura et al. [44] embodied sketching work: capturing the "ephemeral" nature of embodied ideation. In their methods, capturing was primarily achieved through extensive video documentation, often using multiple cameras and angles. This material was not used during the session itself but served as a resource for post-session analysis, reflection, and discussion.

Compared to this approach, the video sticky notes could offer a more participant-driven and in-the-moment means of capturing. Instead of relying on external video documentation for later review by researchers, participants themselves actively choose what to record.

#### Impact of having an interactive prototype

Using an interactive prototype for the evaluation of the concept rather than, for example, a video, could have contributed in surfacing insights that might not have emerged otherwise. The first-person perspective allowed participants to physically engage with the concept, making the system feel more tangible and intuitive. Instead of just observing, they could explore the space, manipulate branches, and experience the system as part of their workflow.

For some participants, this format encouraged playful behaviour and improvisation. One participant, for example, spontaneously handed over a branch to a colleague during the session. This unprompted action led to a discussion on how the system could support collaboration and code review in new ways. Others began experimenting with spatial organization of branches, such as clustering bug fixes near the coffee machine to signal urgency.

These kinds of interactions would not have happened through a video demonstration. The prototype allowed participants to move beyond evaluating features and start imagining how the system might fit into and reshape their real-world practices. This highlights the value of creating interactive prototypes for evaluation of concepts.

#### Designing within the limits of available technology

When designing new interactions in emerging domains like spatial computing and mixed reality, one quickly encounters the limitations imposed by currently available SDKs and hardware. While these tools make it possible to prototype and test ideas outside of lab environments, they also *shape* and *constrain* what kinds of interactions can realistically be designed. This is especially true when working with commercial or publicly available platforms, which often offer a limited set of tracking capabilities, gesture recognition options, and interaction models.

As a result, interaction designers are frequently forced to make compromises based on what the technology allows. In the case of *Spatial Git*, for instance, I had to adapt the gesture design to fit within the technical constraints of the available SDK. Certain interactions that would have felt more natural or embodied simply were not feasible to implement.

This dynamic also shapes the broader landscape of spatial applications accessible to the general public. When the available tools only support a narrow range of interactions, the types of applications that get built (and adopted) tend to mirror those constraints.

#### 8.1.2 On the artefact

#### Movement as an integrated aspect of work

Observations from contextual inquiries with office workers revealed that although standing desks were widely available, they were rarely used. This highlights a broader issue: while modern office work engages some fine motor skills, particularly the hands and fingers, through activities like typing or mouse use, the rest of the body remains largely static throughout the workday. Movement, when it occurs, is often incidental or externally imposed (e.g. being reminded to stand up for a break), rather than arising organically from the work itself.

In contrast, the practices of craftspeople involve full-body engagement. Their movement is not an optional ergonomic intervention but a fundamental part of doing the work. This distinction suggests that simply providing tools or opportunities for movement (such as standing desks or wellness prompts) does not lead to sustained physical engagement. For movement to feel natural and purposeful, it must be meaningfully integrated into the activity at hand.

This aligns with broader perspectives in embodied interaction, where the body is not only a medium of input but also a site of cognition and engagement. Systems designed with this in mind should not treat movement as an add-on, but as a constitutive element of interaction.

The prototype developed in this project serves as an example of how such integration can be designed. By embedding version control actions like checking out, committing, or organizing branches into spatial interactions, the system requires movement that is functionally tied to the task. For instance, retrieving a branch requires walking across the room, handing over a branch becomes a collaborative physical gesture, and organizing branches involves arranging them in space. Movement, in this context, is not an added layer but becomes a consequence of engaging with the system.

#### Physical space in spatial interface design

During the bodystorming sessions for *Spatial workstations*, I observed that the physical work environment had a strong influence on how participants structured their digital tools. Those with fixed desks tended to anchor their setups around their main workstation, using it as a stable and familiar reference point for organizing their tools. This aligns closely with

the findings of Luo et al. [40], where they found that having furniture present in a room assists sensemaking in an augmented reality document organisation task.

A similar pattern was visible during the contextual inquiries with craftspeople. The spatial layout of their workstations directly shaped how they carried out their tasks. The positioning of tools influenced their movements and dictated the flow of their actions. These observations reinforced the importance of accounting for the physical workspace when designing for spatial computing environments.

This insight played a key role in shaping the design of *Spatial Git*. It led me to align certain work processes with the physical layout of the office. For example, shared remote branches were placed in a central location to encourage movement and collaboration, while personal branches were positioned at individual desks to reflect ownership and focus.

One of the key strengths of mixed reality lies in its ability to integrate digital elements within the physical environment. As such, it is essential to consider the spatial context in which an application will be used when designing spatial interfaces.

#### **Reliance on external representations**

A common pitfall in the design of tangible and interactive systems is an overreliance on (external) representations [66]. During the bodystorming sessions for *Spatial Git* and *Skilled text manipulation*, it became clear that imagining skilled actions and movements in isolation from representations proved difficult. Although the goal was to engage participants in sensorimotor experiences, the discussions always reverted to representational thinking in the end.

In many cases, especially in tasks that rely more on representations, such as in te context of this study, some level of such representation is unavoidable. However, by starting the bodystorming sessions with actions instead of first thinking about the representations, this research adopted an action-first, representation-second approach, which helped minimize dependence on symbolic representations for core system operations.

Similarly, by starting with the actions and designing the representations to fit these actions, *Spatial Git* avoids a common pitfall of gesture-based systems, highlighted by Djajadiningrat et al. [13]. They highlight that gesture-based systems often fail to establish a meaningful connection between physical properties and skilled actions, requiring users to learn abstract commands. I would argue that the gestures in this system are not arbitrary but derive from natural spatial interactions. Pushing a branch, for example, fits within user expectations based on the system's spatial logic.

#### Making work visible and tangible through spatial computing

One of the key contributions of this exploration is showing how spatial computing can reintroduce the visibility and tangibility of work that is often present in craft-based professions, but largely absent in office environments. In traditional crafts, works-in-progress are embedded in the physical workspace. They occupy space, signal status, and invite casual interaction or feedback. This physical presence supports awareness, coordination, and a sense of shared progress.

Office work, by contrast, is typically screen-bound. Tasks are buried in abstract systems like Git or issue trackers, making them easy to overlook. As Hornecker and Buur [29] note, tangible interaction offers a way to externalize digital states in material form, allowing people to "think and talk with or through objects".

By visualizing Git branches as spatial objects in the environment, this prototype makes ongoing work physically and socially present. Branches become things you can pick up, move, cluster, or hand over. This transforms the workspace into a kind of shared, reconfigurable project board, where version control is no longer abstract, but integrated into the spatial and social fabric of the workplace.

#### Structuring work through spatial interaction

This research demonstrates how spatial computing can enable a more embodied and intuitive form of organizing digital work. Rather than through abstract lists or screens, branches are laid out in physical space, allowing users to group, prioritize, or sequence them through movement and placement. As Hornecker and Buur [29] describe in their framework on tangible interaction, spatial interaction leverages our natural spatial skills and the inherent meaning we assign to bodily movement and spatial relations.

By engaging users' bodies in interaction, spatial computing turns space into a structuring medium. Participants in the evaluation actively reconfigured their surroundings, clustering related branches or positioning urgent ones near common areas like the coffee machine. These emergent uses align with Hornecker and Buur [29]'s notion of configurable materials, where shifting objects around expresses meaning and intention. Such spatial arrangements are not only practical but communicative and social, supporting mutual awareness and shared understanding in collaborative work.

This approach points to a promising direction for spatial computing and mixed reality research. Rather than seeing MR solely as a method for visual augmentation, it emphasizes how spatial configurations can support thinking, collaboration, and coordination in everyday tasks.

#### 8.2 Limitations

#### **Research scope**

A key factor that shaped the outcomes of this research is the applied perspective I chose to take. Rather than concentrating on the core interactions and what it takes to introduce physical skill into spatial computing, I focused on how such a system might realistically fit into daily office practices. This is a difficult balancing act that many related studies face.

The decision provided valuable insights into the practical relevance and contextual fit of the concept. However, it also meant that less attention was given to the deeper exploration of skill-based interaction itself. A more focused investigation into the development of physical skill might have led to different outcomes, perhaps resulting in a concept more explicitly designed around skill.

#### Perception of the prototype

The prototype developed in this research was intended as a conceptual example rather than a complete solution to a specific problem in using Git. It was not designed to cover the full range of possible interactions in Git.

However, in practice, the prototype (especially those grounded in familiar workflows) was interpreted by users as (almost) finished products. Despite its illustrative nature, the system was evaluated as if it were a final implementation. Because it aligned closely with existing practices, users tended to assess its immediate utility rather than its potential, commenting on things such as the display resolution or weight of the headset. This highlights a limitation of presenting applied prototypes in real-world contexts: their speculative or exploratory value may be overshadowed by practical concerns, making it harder to evaluate *what could be* rather than *what is*.

#### Focus on collaborative context

The prototype was primarily designed with collaborative workflows in mind. As became clear during evaluation, users did not perceive much added value when applying the system to solo projects or contexts with minimal collaboration. In those cases, traditional tools and workflows were often seen as sufficient or even preferable. This emphasis on teambased interaction limited the exploration of how embodied or spatial interaction might support individual workflow.

#### **Context-specificity**

The prototype was shaped by observations within a single software company. While additional bodystorming sessions and insights from two other non-IT organizations helped broaden the perspective, the resulting design closely mirrored the practices, team structures, and tool usage of the primary organization studied. As such, the system may not readily translate to other work environments with different development cultures or approaches to version control. This context-specificity limits the generalizability of the design and raises questions about how adaptable the concept would be across different organizational settings.

#### Generalizability of user group

A key limitation in evaluating the concept of integrating spatial computing into the workspace lies in the composition of the user group. The target audience of the final prototype are tech-savvy professionals who are already familiar with digital workflows, and are potentially more open to new interaction paradigms. This likely made them more receptive to the idea of embodied or spatial interfaces.

One notable exception was a senior back-end developer who questioned the added value of the system, stating a preference for his existing method of note-taking with a physical notebook. This contrast highlights the need to consider how such systems would be received by users embedded in more traditional or analogue workflows.

To better understand the broader applicability of spatial interfaces in professional contexts, future evaluations should target a more different range of users. A prototype tailored to a different user group could yield valuable insights into how various types of professionals might engage with such a system, and whether it could be meaningfully adapted to different work contexts.

#### Challenges of translating computer tasks to human actions

One of the central challenges in this research was translating computer-based tasks into meaningful human actions. By starting from actions rather than visual representation, the design aimed to avoid the common pitfall of relying too heavily on screen-based metaphors. However, the inherently abstract and representation-heavy nature of version control meant that representations could not be entirely avoided.

Furthermore, by mapping digital commands onto physical gestures, I may have made some of the same mistakes found in the field of user interface design. Computer actions are black and white, while human actions are not. While it provided a clear starting point, it limited the opportunity to explore how embodied skill might emerge more organically through interaction. Future research should explore a broader perspective on action—focusing on how skilled movements emerge naturally and how they might inform digital interaction. Rather than forcing human actions to conform to computer paradigms, we should investigate how technology can be designed to align better with human ways of working.

#### 8.3 Recommendations

This research provided valuable insights into designing for skill in spatial computing, but also surfaced limitations in current design methods, technological constraints, and conceptual framing. The recommendations below suggest directions for future research, drawing from both the findings and the unrealized potential identified during the design process.

#### Call for skill-focused design methods

One of the central findings of this project is that the methods used did not lead to a high degree of skilful interaction. While I discussed that part of this could be due to the applied nature of the research, it also points to a need for design methodologies that more directly tap into our ability of skilful action.

Bodystorming methods were introduced as a way to foreground more of the physical body into the process of designing. However, the bodystorming methods used in this study all did not have a effective focus on skills, which can be seen in the results of these sections.

In order to design technology that requires or allows physical skill to be present, we need new methods. A possible starting point for such a method could be focusing on existing skills in humans and exploring how to adapt these in different contexts. Adapting anthropological methods such as presented by Djajadiningrat et al. [13] seems like a worthwhile starting point for this.

#### Strengthen possibilities for sensorimotor couplings in MR

Establishing strong sensorimotor couplings is crucial for enabling skilled action in mixed reality environments. This research again highlighted how difficult it is to achieve these couplings using current digital technologies. Especially the lack of tangibility in the interaction seems like a big barrier. Future work could investigate the role of emerging haptic technologies such as gloves, wearables, or resistive surfaces in expanding the range of feedback modalities available in MR.

Another potential direction to enhance sensorimotor information available, is to use MR to enhance physical objects with digital augmentation, shifting toward physical-digital hybrids that blend tangible affordances with the flexibility of digital content.

#### Explore skilled text manipulation

A valuable direction for future research could to revisit the earlier concept of gesture-based text manipulation, which showed strong potential for skilled use. This idea, based on dynamic control through hand distance and zoom level, was not pursued in this study but remains a promising area for exploring skillful interaction with interactive technology. A follow-up study could focus entirely on this interaction model to better understand how spatial computing might support skillful workflows in individual digital tasks such as editing or writing.

#### Reimagine office work through spatial computing

While this research focused on skill, even without an explicit focus on embodied skill spatial computing could reshape how tasks, files, and workflows are distributed across physical

and digital space. Future research might investigate how spatial metaphors could inform project management, collaborative workflows, or document organization.

#### Spatial computing as a paradigm

A final recommendation is to embrace the term "spatial computing" not just as a buzzword, but as a guiding paradigm for mixed reality interaction. Rather than simply overlaying information in 3D space, a spatial computing approach takes seriously how humans use space to think, remember, and act. This includes how we place objects for accessibility, arrange environments for collaboration, and use proximity and gesture to structure activity. Future work should explore how insights from spatial design, architecture, and embodied cognition can inform MR systems that truly support our being-in-the-world, moving beyond floating menus and toward deeply integrated spatial experiences.

# Chapter 9 Conclusion

In this research, I set out to explore how spatial computing could be used reintroduce embodied skills into office work. Throughout this process which included contextual inquiries with both office workers and craft workers and three types of co-design bodystorming sessions, I encountered both opportunities and limitations in designing for skill within the context of office work and mixed reality. What followed from this process is a prototype with which software developers can work with Git using spatial computing. While the prototype successfully demonstrated an alternative approach to Git version control by making work-in-progress tangible and organizing branches spatially, it did not fully achieve the goal of fostering skilled interactions or craftsmanship.

One of the most significant findings was that while participants appreciated the increased visibility and spatial organization of work, they did not perceive the interactions with the system as (potentially) skilful. True skill development requires sensorimotor coupling and feedback loops, which are difficult to establish within the constraints of current mixed reality technology. The lack of sensory feedback limits the potential for skill emergence, reinforcing existing critiques in the field of embodied interaction.

Beyond the prototype, this research underscores a broader challenge in designing for skill within digital environments: skill cannot simply be imposed through predefined computerlike interactions. Instead, it must emerge through sustained practice and interaction with a system. This raises important questions about whether skilful digital interactions can be deliberately designed or if designers should instead focus on creating conditions that enable skill development over time.

Going through this process first-hand exposed me to the complexities, paradoxes, and technical challenges of designing for skill within the context of spatial computing. By documenting and reflecting on these experiences, I hope to offer valuable insights for designers facing similar challenges.

This research intends to contribute to a broader conversation on embodied interaction, encouraging new ways of thinking about how digital tools can support rather than constrain the natural development of human skill. Looking ahead, I recommend treating spatial computing not just as an industry-coined term but as a significant aspect of mixed reality. By integrating insights from other fields such as spatial design to the existing theoretical underpinning of embodied cognition, we can create spatial experiences that more effectively engage our bodily abilities.

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# Appendix A

# **Contextual inquiry session reports**

#### A.0.1 Digital native jobs

#### (A1) Front-end engineer & project manager, organisation A

The subject serves as both a project manager and a development team leader, playing a pivotal role in the development of a new software feature. Their work involves balancing client communication, team management, and front-end web development.

The subject's workspace is equipped with three monitors, a mouse, and a full-size QW-ERTY keyboard. The monitor layout remains consistent: the browser occupies the right monitor, the development environment (IDE) or active work file is on the centre monitor, and communication tools such as Discord are displayed on the left monitor. This setup seems to facilitate efficient multitasking and minimizes context-switching during work.

Although the subject has access to a standing desk, they primarily work seated throughout the day. As they become deeply engrossed in problem-solving, I observed that they tend to slouch a lot, which the subject acknowledged.

As a project manager, the subject uses Excel to organize and track tasks for the project's duration. They rely heavily on keyboard shortcuts for navigation, reserving mouse usage for more intricate operations. Managing the team involves ensuring each member has work to complete and providing support for problem-solving.

The subject leverages Gitea, a software program for version control, issue tracking, and project management, similar to more popular tools such as GitHub. The kanban-style<sup>1</sup> project board in Gitea is central to their workflow, offering a visual representation of tasks in progress and completed. Weekly team meetings are held to discuss challenges and progress, but most communication occurs asynchronously via Discord and Gitea.

The subject's role as a front-end developer includes coding and reviewing team members' work. They show proficiency with keyboard shortcuts, which makes interactions with

<sup>&</sup>lt;sup>1</sup>A physical or digital board containing cards or sticky notes, that can be moved between different columns representing categories.

the IDE and other tools easier. For example, common tasks such as navigating files, editing code, and debugging are performed almost entirely via keyboard.

Problem-solving is an important part of the work. The subject often has to discuss things with colleagues. If colleagues are present in the office, they prefer direct, face-toface conversations. What often happens is that the subject rolls their chair to the desk of their colleague and sits next to them. Otherwise, if they are not present in person, they communicate through Discord voice calling.

Managing multiple responsibilities requires a structured approach to time and attention. Despite the static nature of their physical setup, the developer's mental focus shifts fluidly between different tasks of completely different nature. Interruptions, such as client inquiries or team issues, can break concentration.

#### (A2) Front-end engineer & project manager, organisation A

Subject A2 is a front-end engineer and project manager, the same job position as subject A1. The subject's responsibilities include project management, front-end development, and extensive communication with both internal team members and external stakeholders.

The subject works on a laptop connected to two external monitors. The workspace is structured into three main areas: the issue tracker (Gitea) is displayed on the laptop screen, the browser used to preview the website under development occupies the right monitor, and the primary task—writing or editing code—is performed on the central monitor. This is a similar setup to the other developer and seems to facilitate three important steps in the work: task management, execution (writing code) and validation (seeing if the code that is written works the expected way).

A notable aspect of the workspace is the coincidental presence of a football on the office floor. The developer occasionally rests their feet on it or idly plays with it while working. This small physical activity appears to serve as a stress reliever or focus enhancer during the workday.

The subject showed me the use of Git version control to manage code changes. After completing a new feature, they prepared the code for integration into the main branch by using a graphical user interface (GUI) within their IDE to push and commit changes. Before this code is merged into the codebase of the actual environment, it should be reviewed by someone else. This ensures that no faulty code is added to the codebase.

Unlike some developers who minimize mouse usage, this developer relies more heavily on the mouse for navigation and interactions. The other developers that were present while doing this contextual inquiry told me that they consider a developer who is able to minimize their usage of the mouse to be a more skilled developer. This seems to be a combination of professional identity and actual useful skill, as it can make processes faster.

When deeply focused or searching for a solution, the developer leans closer to the screen, a physical indicator of concentration. The use of headphones helps maintain focus,

aligning with the observation that developers often inhabit a highly concentrated "world of their own." Interruptions are generally avoided unless necessary.

#### (A3) Back-end engineer, organisation A

Subject A3 is a back-end engineer at organisation A, The subject works as part of a fivemember team, including two senior engineers. The informal and collaborative nature of the workplace heavily influences the subject's daily activities. The subject primarily utilizes tools such as Gitea for version control and task management.

The subject's workspace consists of a desk in a small open office containing three computer monitors, a mouse, and a full-size QWERTY keyboard. The screen layout remains consistent across tasks, with communication channels displayed on the left monitor, the development environment (IDE) on the middle monitor, and documentation and task management tools (Gitea) on the right monitor.

The subject's work involves a variety of activities related to task management, version control, code editing, communication, and referencing documentation. Task management and project boards are handled using Gitea. While this software has the ability to include rich and detailed planning information, the subject noted that the tool is not utilized to its full potential as a collaborative resource. The project board, a kanban-style overview of 'issues' primarily serves as a reference point and a repository of historical decisions. However, communication about task status and responsibilities remains an ongoing organizational challenge due to the absence of structured leadership. Gitea is also used for requesting and executing code reviews.

For version control, the subject prefers using an external IDE instead of the built-in Git tools, citing usability challenges. The chosen IDE enhances clarity by providing a GUI, which simplifies code comparisons and tracking changes. During the code editing process, the subject relies heavily on keyboard shortcuts, minimizing mouse usage. Common operations include copying and pasting code snippets, rapid navigation using arrow keys, and selecting text with Shift and arrow key combinations.

Communication is another important aspect of the subject's workflow. They prefer inperson discussions with senior developers for resolving complex issues, which they find more effective than remote communication. However, because of the hybrid nature of the company, this is not always possible with some colleagues working from home. Documentation is frequently consulted to inform coding decisions and ensure compliance with project requirements, making it an integral part of the workflow.

The subject demonstrates a high level of proficiency in keyboard navigation within their IDE, even though they do not identify as a touch typist. During code creation, trial and error play a significant role in their process, facilitated by the low-risk nature of digital work. Notably, the subject seldom uses their mouse, relying instead on an efficient combination of keyboard shortcuts to streamline their workflow. For instance, their right hand is almost always on the arrow keys, while the left hand executes various shortcuts such as Ctrl+C

and Ctrl+V for copying and pasting code snippets.

The subject's workflow is characterized by iterative problem-solving and multitasking. Trial and error is a recurring theme, as the subject often experiments with different solutions. Unlike larger organizations where software architects and developers are separate roles, the subject handles both architecture and development. While they find this dual role challenging, they consider it efficient for a small team. However, they also acknowledge the importance of centralized discussions on software architecture and believe tools like whiteboards could enhance collaboration and decision-making processes.

Although the immediate goal of their work is functional code, the subject places significant emphasis on improving code quality over time. Their approach involves first establishing a solid baseline before refining the framework and optimizing the code structure.

#### (B1) Data analyst, organisation B

The contextual inquiry with subject B1 had a slightly different course than the other contextual inquiries. The subject was much keener to talk about his job than to actually show himself at work, so opportunity for actual observation was limited. However, there were still some interesting takeaways that could be made.

Subject B1 works as a Data analyst within the organisation. He uses data in Microsoft PowerBI to create dashboards and reports about certain statistics in the company. This information is than used to inform the organisation about certain decisions.

The subject's setup involves three-screens. The central monitor is dedicated to working with Power BI, the right monitor is primarily used for browser activities, and the left monitor, which is the laptop screen, is mainly used for email. Organisation B has a flexible office policy. This means that there are no fixed desks assigned to any employee. However, this employee did unofficially claim their desk, against company policy. They also put some paraphernalia on the desk to further make it their own. This seems to suggest some desire to create their own working environment.

This subject has been working at this organisation for a long time, and the way he spoke about his job seemed to reflect a craftsman-like involvement in his work. He spoke with great passion about his role within the company, and how he tries to keep improving his practices.

The participant's workflow is characterized by a high degree of exploratory activity. Their work often requires investigating different possibilities and testing configurations within Power BI. A significant part of the participant's work involves managing and analysing columns of data within Power BI. They frequently utilize the tool's relational view, which employs a node-based database interface. This view facilitates the construction and visualization of relationships between data tables.

#### A.0.2 Other office jobs

#### (B2) Communications advisor, organisation B

Subject B2's role involves strategic coordination of all client-facing communications, including social media strategy and terms and conditions. The job is primarily a strategic and tactical one, with an emphasis on planning and organization rather than direct content creation.

The subject's workspace consists of a desk equipped with two computer monitors, a keyboard, and a mouse. A laptop is used as computer with the lid closed. While the desk is adjustable for standing, it is used exclusively in a seated position. The subject uses both monitors for different purposes: Microsoft Teams is displayed on the right screen but is mostly ignored, while the left monitor is used for everything else. There does not seem to be a very mindful organisation of 'what-goes-where', like I have seen in the observations with developers. The subject's interactions with their computer are characterized by frequent tab switching, though the majority of their work is concentrated on a single active screen. The subject has another screen available but does not utilise it.

The subject's physical activity is minimal, with little to no engagement of lower extremities during work. A notable interaction occurred when they adjusted their screens (lowering them slightly) to communicate with a colleague across the desk, or standing up briefly to do so.

The subject's primary responsibility involves coordinating communications with the clients of the organisation. Today's task that I have observed was reviewing and approving a new version of the terms and conditions for tenants. The review process is thorough, involving multiple iterations and feedback cycles marked with digital sticky notes through Adobe Acrobat.

A recurring theme in document review is the iterative nature of the process, involving multiple "final" versions. This highlights the challenges of version management in collaborative work, where clarity and organization are crucial to maintaining progress.

Task prioritization is driven by the calendar, which acts as the central organizing tool. Outlook is used to schedule tasks and meetings. Incoming emails are meticulously sorted into folders, reflecting the subject's highly organized methodology. Despite this structured system, the role demands flexibility to address ad hoc questions and issues that arise throughout the day. This balance of structure and adaptability is critical to managing the workload effectively.

Collaboration occurs in both formal and informal settings. Formal meetings are typically held in dedicated meeting rooms, while informal discussions often take place around desks. The subject's posture shifts noticeably during these interactions, leaning back during informal conversations and adopting a more upright position in formal settings.

While I observed subject B2 working on a specific task today, their workload can vary significantly from day to day. This variability is a common characteristic of many office

jobs, contrasting with more trade-oriented roles such as code development, woodworking, or barista work, which tend to involve more repetitive and predictable tasks.

#### (B3) Communications specialist, organisation B

Subject B3 is responsible for creating and managing content, coordinating communication across multiple platforms, and handling various tasks that differ significantly from day to day. While both working in the communication department, subject B3's role differs from B2's role in the sense that their role is more hands-on, where B2's role is more strategic.

The subject works with a dual-monitor setup: one screen is dedicated to emails and MS Teams, while the other alternates between other tools. The workspace includes a notebook for jotting down comments and reminders. While the digital setup facilitates multitasking, window management appears slightly unorganized at first sight, with overlapping applications requiring frequent adjustments.

One notable challenge is the impact of interruptions. Email notifications and other prompts can disrupt the subject's focus, leading to frequent task switching. The lack of a highly structured workflow might stem from the need to respond quickly to incoming requests from colleagues, but it also results in tasks being revisited multiple times before completion.

The subject's workflow is marked by a fluid, non-linear approach, which seems a little bit disorganised. Tasks often remain partially completed as new ones arise. For instance, the subject may begin drafting an email but shift focus to another task before finishing. This could reflect the nature of the role, which requires juggling multiple responsibilities and addressing tasks with varying timelines.

Task completion frequently involves collaboration. Many assignments, such as creating communication materials, require feedback from multiple sources. Feedback mechanisms vary—sometimes delivered directly through comments on the material, other times as a consolidated list via email.

The subject's physical posture shifts depending on the task at hand. While typing, they adopt a more relaxed posture, occasionally pausing to think. In contrast, close reading or editing involves leaning toward the screen with a slight hunch and a noticeable head tilt, reflecting increased focus and tension. Typing and reviewing tasks appear to engage different cognitive and physical states. This binary shifting between relaxed typing and tense reviewing suggests a physical posture tailored to the demands of specific tasks.

The way the subject manages their windows seems to suggest there is some cognitive process in the process of organising application windows. Sometimes windows are dragged next to each other, sometimes they overlap. This seems to be determined by the relationship between the windows. For example, the subject detaches their calendar view from the email application temporarily to cross-reference schedules before reintegrating it. This active managing of windows instead of them statically present on screens is seems to suggest some kind of active engagement with them.

#### (C1) Movement advisor, organisation C

The subject's role centres around promoting healthy lifestyles through various activities, including creating and reviewing content, conducting meetings, and facilitating physical activity initiatives. The workplace culture supports an active lifestyle with elements such as promoting cycling to nearby locations and standing desks, but these features are not consistently integrated into daily workflows.

The subject uses a laptop connected to an external display, a full-size keyboard, and a vertical ergonomic mouse provided by the organization. The laptop is often placed on a stand for better ergonomics. Although standing desks are available in the office, the subject typically works from a seated position. The office employs a flexible desk policy, meaning no one has an assigned workspace. Meetings frequently take place in designated spaces with standing-only tables.

The subject's tasks are highly varied, encompassing content review (e.g., checking a flyer about healthy shakes), meetings, and general administrative duties. Their workflow involves using Outlook for calendar management in combination with a physical to-do list in a notebook to organize their tasks. They spend much of their time on a computer, performing a mix of activities such as writing, reviewing documents, and conducting research. Often, multiple browser tabs and applications are open simultaneously, necessitating frequent switching between window layouts. Similar to subject B3, this active management of application windows seems to be part of the active cognitive involvement - a sort of thinking through moving the application windows. Another interesting behavioural pattern observed was the subject selecting text on a screen to focus their attention to that line, which appeared to aid in processing information.

During meetings, the subject primarily relies on a notebook for note-taking, occasionally using the pen to gesture or emphasize points during discussions. Writing by hand introduces pauses that sometimes disrupt the workflow but can also create opportunities for reflection and summarization. Meetings occur in spaces equipped with standing tables. The subject brings both their laptop and notebook, but interaction is predominantly focused on physical note-taking. Closing the laptop often signified the meeting's conclusion.

Despite the subject's role emphasizing physical activity, their daily workflow involves extended periods at the desk. On more stationary days, the subject feels the physical strain, mitigated occasionally by brief walks or ergonomic setups. Small acts of movement, such as taking occasional lunch walks, provide some relief. However, these activities are sporadic and do not consistently counterbalance long sedentary periods.

#### A.0.3 Physical jobs

#### (D1) Barista, self-employed

Subject D1 is works in a small self-owned espresso bar. This means that the subject handles multiple responsibilities, including beverage preparation, customer service, and equipment maintenance, all while maintaining a steady rhythm and flow in their tasks. Despite it being a relatively quiet day with fewer customers, the barista exhibited constant movement and engagement with their environment.

The coffee station is organized what seems to be a way to support the barista's workflow. The bar features four grinders, an espresso machine, cups, and a water station with a flusher. Adjacent to the bar are a counter and a point-of-sale (POS) system for taking orders and serving customers. Under the counter, there is an industrial dishwasher and a fridge, providing easy access to essential tools and supplies. This setup ensures smooth transitions between tasks.

The barista's workflow revolves around a series of repetitive yet precise motions. The preparation of each coffee drink follows a consistent rhythm:

- Clean the piston with a cloth with a quick circular motion and hang it on the grinder. The grinder will now dispense ground beans into the piston.
- While grinding beans, retrieve a cup from the top of the coffee machine.
- Mix the grounds using a small needle tool and tamp them into the piston using a tamper. Here it is important to use the right amount of force while tamping.
- Insert and twist to lock the piston into the espresso machine and press the button to start brewing.
- Remove the used grounds by slamming it into a bin and wipe the piston clean.

For milk-based drinks, the barista incorporates milk steaming into the routine. This is an interesting multisensory practice that relies on both sound and touch. The barista listens for the correct pitch of steam incorporation. The sound that the steam wand makes when interacting with the milk informs the barista if they are incorporating the correct amount of steam into the milk. At the same time, the subject gauges the temperature of the milk by touching the jug, ensuring it does not become too hot. Mastery of these sensory cues requires practice and experience. The subject told me he received extensive training to be able to do what he does.

The barista also adjusts the grinders daily, particularly in the morning, to account for changes in the beans' properties. As beans age (typically one to four weeks old), their behaviour during grinding and brewing changes. The barista measures brew times and makes constant adjustments to ensure optimal extraction, a process that becomes an ongoing task with fresh beans. Task management is a critical component of the barista's role. Although some tasks can be deferred, customer service takes precedence. When a customer enters, the barista must balance attending to them promptly while completing drinks for previous orders. The workflow accommodates parallel processing, allowing multiple orders to progress simultaneously. For instance, while a shot is brewing, the barista may prepare milk for steaming, retrieve cups, or begin cleaning the piston. This ability to interweave tasks ensures efficiency during busier periods.

Despite the rhythmic nature of the work, interruptions occur, such as customers entering or requiring assistance. These interruptions can temporarily break the flow, requiring the barista to quickly recalibrate their focus. Balancing competing demands while maintaining quality is a constant challenge in this role.

#### (E1, E2) Two carpenters, self-employed

At the time of observing, the two carpenters were working together on furniture for a DJ-studio. The shared workshop is a busy and somewhat cluttered space, with tools and materials dispersed across various workstations. Despite the limited space, the woodworkers demonstrate an effective and adaptive approach to their tasks. Many of the tools in the workshop are movable, allowing the workers to reconfigure the space as needed to accommodate their projects. Fixed tools are positioned strategically, while portable tools are shared among workbenches, enabling flexibility and collaboration.

The nature of the work often requires manoeuvring large pieces of wood, necessitating significant physical movement. Workers frequently duck down to pick up materials and walk around their projects to access different areas. This dynamic interaction with their workspace reflects a balance between the physical demands of woodworking and the spatial constraints of the environment.

For tasks requiring intricate detail, the workers physically move closer to their projects, not only to see better but also to become more engaged with the process. This "zooming in" shows a deeper connection to their craft and enhances focus on fine details. Power tools, such as sanders, are used for initial stages of an operation, while non-powered tools are often employed for the finishing touches. When asked about this, the carpenters answered that hand tools allows them to gain a tactile understanding of the material and achieve a finer finish.

After completing tasks, such as cutting or sanding, the subjects place finished pieces at a designated collection point to keep the workspace organized and ready for the next stage of work. The fact that there is limited space, and the materials large, requires the subjects to very mindfully execute their work. They constantly need to stay organized. An example of this is seen when one of the subjects is cutting wide strips from a large board. After every cut, he needs to place them at a different location which has been prepared for these boards, before he can continue to the next cut.

# Appendix B

# Spatial setups

#### B.0.1 (C2) HR Manager, organisation C

This participant works as an HR manager in organisation C. She did not participate in the earlier observation sessions. This was her first encounter with MR, and she was both impressed and inspired after a brief exposure. The session took place in her own office space, which is shared with one other person.

To start, the subject detailed their tools and noted their purposes. While doing this exercise, I realised that it would be beneficial to reflect more deeply on the tools at this stage. To facilitate this, I asked the subject to also note the usage frequencies (expressed as percentages), how often the tools were used in conjunction with one another, and whether each tool primarily served as an information source or involved more advanced interactions.

The participant placed her e-mail application on the spot of her current computer screen. She identified e-mail as her primary tool, deserving a central spot. The other applications were all placed relative to that spot. She placed her calendar tool on a whiteboard next to the entrance. At this spot, there was already a physical year planner present, so it made sense for her to put it next to it. Also, she remarked that this is a logical spot because her colleague could see it from this location as well. Additionally, she remarked this could be a good spot because she could glance at it from her desk while needing to walk towards it to interact with it.

There were several tools she used for her job more infrequently. The participant bundled these and placed them in a stack on the opposing wall. The topmost tool in the bundle required occasional checks, while the others were primarily action-oriented.

Finally, MS teams was placed on the wall behind the sitting location. They reasoned that its infrequent and short use justified its location. Additionally, this placement encouraged her to move physically during the day for a more active workflow.

ID	Tool	Use	Location	Reasoning
1	Outlook	E-mail	Over the current computer screen	She immediately identified Outlook as her "base" tool and placed it prominently over her computer screen, remarking, "I see this as the foundation, so I'll just stick it here."
2	Calendar	Planning day	On whiteboard next to the entrance	After some deliberation, she placed it next to a wall- mounted poster of a year planner near the entrance. This place was chosen so that her colleague could also see it, as it is a central spot. She remarked that she could glance at it from her desk and interact with it by walking to- wards it.
3	Daywize	Digital em- ployee files	Bundled with tachiplan, arbo, and validsign, with daywize on top of this stack. Placed on opposing wall to the desk	These were all tools that were less frequently used and al- most always used in combi- nation with each other. She grouped them into a bun- dle, which she placed further from her desk. The topmost tool in the bundle required occasional checks, while the others were primarily action- oriented.
4	Tachiplan	Making timetables		(Grouped with above)
5	Arbo	Absence registration		(Grouped with above)
6	Validsign	Digital doc- ument sign- ing		(Grouped with above)
		-		(continued on next page)

# Table B.1: Overview of spatial setups for C2

#### (continued from previous page)

IDToolUseLocat7TeamsStoringPlacedocumentscation

Location Placed behind sitting location on the wall

#### Reasoning

They reasoned that its infrequent and short use justified its location. Additionally, this placement encouraged them to move physically during the day, which promotes an active workflow.

#### B.0.2 (B4) Senior communications specialist, organisation B

This session took place in a workplace with a flexible desk policy, meaning the participant did not have a fixed desk to use daily. Because of this, all desks are about the same and contain no personal elements. I suspect this context could have an effect on the amount of consideration and attention these employees give to their physical workspaces. It is therefore also interesting to see if it influences the outcomes of the bodystorm sessions.

The participant suggested to use sticky notes to represent application windows during the session instead of my suggested pieces of paper. However, this choice turned out not ideal, as sticky notes are much smaller than A4 papers and did not adequately represent the scale of actual windows. Instead, the sticky notes functioned more like icons, which was not the intended goal. This made it difficult to understand how the participant perceived and interacted with her tools in a realistic context. For future sessions, A4 papers will be reintroduced to better simulate the size and usability of application windows.

The participant identified a large number of tools, many of which were used infrequently. This created an overwhelming number of items to work with during the session and diluted the focus. In hindsight, limiting the number of tools in future sessions would encourage deeper engagement and a more thoughtful exploration of priorities. When organizing her tools, the participant placed them quickly without much (visible) deliberation or verbal explanation. This lack of reasoning made it difficult to discern the logic behind some of her choices.

The participant placed communication apps, email, and their calendar on her computer screen.. These tools were described as the most important and were used consistently throughout the day. However, their arrangement on the screen appeared unstructured, as the participant simply placed them there without organizing them in a specific way.

Intranet tools were positioned slightly off to the side of the main workspace. The participant valued having these tools easily accessible for occasional glances but did not consider them integral to the core workflow.

After this, the participant started placing the remaining applications on the window, sorting them on her perceived important for her workflow. This meant that more important applications would live closer to her main setup, while less important applications would live further away from her.

#### Table B.2: Spatial setups participant B3

ID	Tool	Use		Location			Reasoning
1	Whatsapp Web	Commu	nication	Over the screen	current	computer	Part of the most important tools in her work
2	Outlook Calendar	Task ment	manage-	Over the screen	current	computer	"

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ID	Tool	Use	Location	Reasoning
3	Outlook mail	Communication	Over the current computer screen	"
4	BUUR	Intranet, commu- nication	Off to the side, glanceable, together with other intranet tool	Nice to occasion- ally check
5	Nico	Intranet, commu- nication	Off to the side, glanceable, together with other intranet tool	Nice to occasion- ally check
6	File ex- plorer	File management	Over the current computer screen	Part of the most important tools in her work
7	Google	Reference	On the side, together with snipping tool and Word	Often used to- gether when making things
8	Snipping tool	Copying and past- ing from several resources	On the side, together with Google and Word	Often used to- gether when making things
9 10	PowerPoint Word		On the side, next to facilitator On the side, together with Google and snipping tool	Used occasionally Often used to- gether when making things
11	Excel		On the side, furthest away from the desk, together with OneDrive	Rarely used
12	MS Teams	Collaborating on different files with colleagues	Over the current computer screen	Part of the most important tools in her work
13	MS OneDrive	Save location for files	On the side, furthest away from the desk, together with Excel	Rarely used
14	Afas	HR program for invoices, absence, etc.	On the side, further away from the desk, together with Empire	Rarely ever used
15	Empire	CRM System	On the side, further away from the desk, together with Afas	Rarely ever used
16	Facilitator	Desk reservation system	On the side, next to Power- Point	Used every day, but only once

#### B.0.3 (B2) Communications advisor, organisation B (also participated in contextual inquiries

This bodystorm session was conducted with a participant who also had previously been observed in their day-to-day operations during an earlier iteration of the study. Unlike their desk environment, this session took place in a small meeting room equipped with a large TV screen. The change in environment provided an opportunity to observe how the participant adapted their workflow in a different setting.

Despite not having a desk in the space as a central point, the participant showed a tendency to centre their organization around a focal point. In this case, they used MS Word as the central anchor, as they explained that in that program their main tasks take place. Where this focal point was the existing computer screen in the previous cases, here the participant placed the window on the glass entrance door after some deliberation. Next to this focal point, the participant placed tools that helped them in writing, such as ChatGPT and a website to check text difficulty level, in a sort of 'reference' position.

Another interesting observation was the participant's choice to place communication tools such as WhatsApp and MS Teams in a dedicated space, similar to a phone booth. When asked whether this separation might lead to missed communications, they explained that the separation was deliberate and designed to minimize interruptions.

The participant identified their calendar and email tools as essential components of their workflow. While these tools are important, they are not accessed continuously throughout the day. Instead, the participant prefers to engage with them deliberately during specific moments. To reflect this intentional use, these tools were positioned opposite the primary tool, which in this case was MS Word, opposite the door. This had as a side effect that that upon entering the room, the participant's schedule and inbox are immediately visible.

In contrast, tools that were used less frequently were stored in a designated 'shelf' area at the back of the room. The participant described these tools as 'standalone, in the back of my head', emphasizing their supportive yet secondary role. These tools are not part of the daily workflow but are retrieved when needed to assist in specific tasks. By positioning them on a conceptual storage shelf, the participant ensures that these tools are accessible without cluttering the primary workspace, reflecting an organized and intentional approach to tool management.

At the end of the session, the participant mentioned that the physical organization they created during the session was not only an interesting artefact of how a spatial workplace could look like, but also a reflection of how they structure their work mentally. This insight suggests that the spatial arrangements could help structure or support cognitive workflow.

ID	Tool	Use	Location	Reasoning
1	Outlook	Planning/	On wall opposite	These should always be present,
	Calendar	meetings	entrance, and be- hind the person if working in Word, clustered with mail	but it is not information that is glanced on when working on something. It is something they deliberately want to go to. Placed opposite the main tool (Word), which so happened to be placed on the door. So if walk- ing into the room, they see their schedule and inbox. Not done all the day, but just some moments per day
2	Outlook Mail	Communication/ informing	On wall opposite entrance, and be- hind the person if working in Word, clustered with mail	Almost always used together.
3	Teams	Communication/ file manage- ment	A separate desig- nated space	"Most fun would be, if I would need to contact someone, I would have to go to another place." Comparable to the idea of a phone booth — "just so you are removed from your current work for a bit."
4	BUUR	Intranet	A bit further away to the left of Word, glanceable	"Intranet is a bit in between [communication and productive work], mostly at-a-glance infor- mation. Mostly as input for other things. It is information I need to have, but it is not like I cannot do my work without it."
5	ishetb1.nl	Writing help (checking text difficulty)	Next to Word, to- gether with Chat- GPT and Google, in a sort of stack.	Important resource used to- gether with Word. Placed in a stack on the same place, because not used at the same time, but always next to Word. <i>(continued on next page)</i>

## Table B.3: Spatial setups participant B2

# (continued from previous page)

ID	Tool	Use	Location	Reasoning
6	ChatGPT	Writing help	"	27
7	Google	Looking up things	"	"
8	WhatsApp	Calling/ com- munication	A separate desig- nated space	Same as Teams.
9	Word	Writing copy / creating plans	On the back of the door towards the exit	Put in the middle because when "really creating something", she uses this the most.
10	Canva	Creating visu- als/ presenta- tions	On a 'shelf' in the back, together with Vormats and the CMS system	"These three are standalone, in the back of my head." These are tools that are retrieved as sup- port when making something, not used every day. They should live on some sort of storage shelf.
11	Vormats	Creating/ edit- ing video	"	"
12	CMS sys- tem	Uploading content	"	"

#### B.0.4 (C1) Movement advisor, organisation C (also participated in contextual inquiries)

The bodystorm session was conducted with a participant who had previously been part of the observational study. The session took place in her shared office, where four desks were present. However, during the session, the participant was the only one present in the space.

The participant's approach to tool organization in this session differed from previous observations. While she described her arrangement of the tool as random, her focus was less on fixed locations and more on bundling related tools together. She emphasized that the positioning of tools wasn't fixed or essential to her; everything could potentially be rearranged, even outside the office. However, she highlighted the importance of grouping frequently used tools, such as Excel, HDI (a tool for data reports), and PowerPoint, as these are often used together. Without them being close together, she noted, moving between them could become cumbersome.

The participant expressed that she was more inclined to move windows around than to physically relocate herself. She conceptualized her tools as akin to books on a shelf, items she could grab as needed but did not necessarily require a predefined structure.

She noted a preference for standing when using tools that are accessed occasionally, such as Google, as this added an element of physical activity. However, for tools requiring longer use, she preferred them to be within arm's reach of her sitting position. Tools were therefore grouped by their relevance to one another and their frequency of use. For example, she placed Word directly over the computer screen to serve as the central anchor of her workflow. This allowed her to either stand or sit while working. She grouped Excel, HDI, and PowerPoint together on the wall to the left of her sitting position, because these are used together quite a lot.

#### Table B.4: Spatial setups participant C1

ID

Tool 1	Use Outlook in- box	Location Incoming e- mails	Reasoning Together with outlook search on a location be- hind the sitting position	Placed together again, but it made more sense to put them together. Placed them in this location quite indifferently.
2	Outlook search	Finding a specific e-mail	Together with outlook inbox on a location be- hind the sitting position	
3	Google	Search and find	Directly behind the sit- ting position	For the occasional search.

ID 4	Tool Monday	Use Logging tool, project	Location Next to Google on the wall next to the sitting positing	Reasoning Placed it a bit further away, in the 'administration closet'
5	Powerpoint	manage- ment Creating presenta- tions	On the wall left of the siting position, clus- tered with excel and	Placed together, because otherwise I have to much distractions.
6	Excel	Data analy- sis	HDI On the wall left of the siting position, clus- tered with powerpoint and HDI	
7	HDI	Data re- ports	On the wall left of the siting position, clus- tered with excel and powerpoint	Use it often always together with excel and powerpoint
8	Outlook agenda	Task man- agement + creating meetings	Next to the main win- dow to the left, glanca- ble form the sitting po- sition.	
9	Word	Writing	Over the current com- puter screen	I use it a lot. I want to have the free- dom to stand up and sit down. Cen- tral to the workflow.
10	File man- ager		Below the word win- dow	It is my search bar
11	Sharepoint	Managing online files and forms	Next to the main win- dow to the right, glan- cable form the sitting position.	Don't use it that often as files, but still need it.

#### B.0.5 (B1) Data analyst, organisation B (also participated in contextual inquiries)

The bodystorming session with the data analyst took place in a medium-sized meeting room, as the previous bodystorm in a meeting room seemed more successful then in a flexible working space. However the participant did not utilize the available space. They placed all windows on the same wall, showing a two-dimensional approach.

The participant placed PowerBI at the centre of the workspace, identifying it as the primary tool used throughout the day. All other applications were positioned in reference to this main window, with tools that are used in combination with PowerBI, such as Excel and Empire placed close to it.

The participant created a 'menu bar' along the bottom of the wall, where lesser-used applications were positioned for quick access to secondary tools. This strongly resembled the functionality of traditional desktop operating systems.

Outlook and Microsoft Teams were placed on the far left and far right of the wall respectively, far apart from each other. When asked why they placed these tools which were similar in utility so far from each other, they mentioned that it is company policy to mainly use Teams for communication. However, most colleagues do not adhere to this policy. They placed Outlook further away out of protest as they would rather not use it at all.

The data analyst stated that they do not want to place anything on the side walls. They saw no need for additional space between applications, as open windows do not distract them. The subject preferred to have everything open simultaneously for easy reference, allowing them to glance at information without switching views. The data analyst mentioned that this approach mirrors how they create reports, prioritizing maximum visibility of data at once.

Table B.5: Spatial setups participant B1

ID	Tool	Use	Location			Reasoning
1	Outlook	Email	Right of the of windows	main gro	oup	
2	Word	Making manuals or analysis	Adjacent PowerBI	right	of	

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(con	tinued from pr	evious page)		
ID 3	Tool ChatGPT	Use Asking questions, mainly about DAX formulas used in PowerBI	Location In the bottom row	Reasoning Things I don't have open all day, but that I do want to be able to easily switch to.
4	LinkedIn	Sharing messages and read- ing about trends	In the bottom row	(Same as above)
5	BUUR	Reading up- dates from colleagues	In the bottom row	(Same as above)
6	Empire	Referencing for data used in PowerBI	Adjacent to the bottom of PowerBI	Is an important source for using PowerBI.
7	Excel	Analysis, making pivot tables	Adjacent left from PowerBI	Needs to be close to PowerBI — this makes it easy to move things be- tween PowerBI and Excel.
8	CBS	Data portal, getting data to use in PowerBI	In the bottom row	Do not use this a lot. By placing it in a bar at the bottom, I can retrieve it when I need it.
9	PowerBI	Creating and main- taining reports	Placed in the middle. All other windows placed in reference to this main window.	This should take up the main space that is available, as it is the program used the most, by a large margin. I want to see it the best — would make it large.
10	Teams	Communicati with groups within the company	ngeft of the main group of windows	0

# Appendix C Spatial Git sessions

#### C.0.1 Session 1

During this session I invited two peers of mine, both front-end web developers that have experience with human-computer interaction through their study programmes and student jobs. This created a optimal set of conditions for this bodystorm. These participants have experience with using Git first-hand, while also feeling comfortable enough partaking in this co-designing bodystorm. I took an active role in this session, which took about an hour in total.

We began the session by listing the main Git actions and their effects (push, commit, pull, merge, and creating new branches). This served as a foundation for our exploration. For each of these actions, we ran through a similar process: first, we had a short, personal intuitive exploration of the action. This exploration was not recorded to the sticky notes. This initial exploration was discussed with each other, after which several of these sketches were recorded on the sticky notes. Having saved the sketches to the sticky notes, we moved on to the next action. A full overview of the sketches can be found in Appendix C

These initial sketches were not only a means to visualize the gestures but also a way to delve into and discuss their meanings. This deeper exploration led to meaningful discussions about the personal interpretations of these Git actions. We found that the meaning of certain actions, like committing, can vary greatly between individuals. For some, committing represents a waypoint in their work, while for others, it's akin to saving a document. Through discussion, we drew analogies, such as comparing committing to a carpenter setting aside a piece of work after making a precise cut. We also debated the deliberate nature of committing, noting that a clear, descriptive commit message is key to better documentation, even though not every developer takes the effort to do this. We explored sketches for committing with gestures such as grabbing and placing something on a virtual shelf, taking a snapshot with the hands and labelling it, or making a pushing motion to symbolize imprinting.

Because of the language used to describe the Git actions, some actions caused a quite straightforward intuitive movement. An example of this is Git pull, which we initially represented by a literal pulling motion. However, while we were doing this, we explored how the gesture's execution depends on what you are pulling and where you are pulling from. The gesture does not live in a vacuum. We also explored pulling in a collaborative team context, where one person pushes changes, and another pulls them. This raised the question of how shared spaces might function, with the idea that collaboration should be grounded in a central, shared location rather than being user-centric.

For merging, my initial intuitive movement would be to push my hands together, as to fuse two things together. However, the participants noted that this seems inaccurate to them. This Git action does not merge two equal things into one, instead often one subordinate branch is merged into a main branch. This influenced how this merging was symbolized. One participant noted how their IDE's (WebStorm) visualization of merging influenced their perception of this merging process.

After this, we explored the different "locations" in Git where changes are stored (working directory, local repository, remote repository, skipping the staging area since this felt less essential for the workflow). We conceptualized the working directory as something that is closest to the user; on the desk or even on the person themselves. This lead to the idea as the working directory to be something like a necklace or amulet that the developer wears as they are working on a piece of code, with each commit adding a gem to this necklace.

We saw the local repository as a place still in the vicinity of the person, but a bit further away. Here, the code is still only possessed by this person, but a snapshot of it is stored. Finally, we saw the remote repository as something that is further removed from the user. This led to discussions about the role of physical office spaces in representing these locations. It seemed logical that local items should be within immediate proximity of the user, while remote items should occupy a separate, central space that everyone could access.

Table C.1: Results of first bodystorming session for Spatial Git

ID

### Action Description

1	Commit	Pushing down with two hands
2	Commit	Making a turning motion with one hand, as if locking something with a key
3	Push	Pushing up with two hands
4	Push	Making a throwing motion, as if throwing a basketball
5	Pull	Pulling with one hand from the front towards the self, with the hand closed
6	Pull	Pulling with two hands from the sky
7	Fetch	With two hands, making a revealing motion

## Action Description

0	Fotob	With one hand, making a revealing motion, as if presenting some-
0	rettii	hting
9	Fetch	Turning the head back to look up to the ceiling
10	Merge	Grabbing from the sky and moving that hand to another hand
11	Merge	Putting two branches on top of each other, and stomping down with a foot
12	Checkout	Grabbing from the sky, and placing it on the desk

#### C.0.2 Session 2

The second bodystorming session for Spatial Git was conducted one week after the first session. This time, the group consisted of one experienced back-end engineer (A3) and one front-end engineer (A4). The inclusion of both a back-end and a front-end engineer provided an interesting mix of perspectives. The back-end engineer contributed a more technical and structured way of thinking, while the front-end engineer offered insights more grounded in user experience and design. Just as in the previous session, I took on an active role in the session as a co-designer while avoiding steering the conversation too much. A full overview of the movements that were created in this bodystorming session can be found in Appendix C

We began the session by listing the primary Git actions. Interestingly, the group identified a slightly different set of actions compared to the first session: commit, push, pull, fetch, merge, and checkout. We discussed and recorded the meanings of these actions and noted the varied ways developers use them. The back-end engineer pointed out that committing, for example, can range from frequent incremental changes to larger, more deliberate updates once a piece of code is complete. This sparked a discussion about metaphors to explain the commit action, such as 'imprinting,' 'putting something to the side,' or even 'curing a resin 3D print with UV light to lock it in.' These metaphors shaped the group's ideas for commit gestures, which included turning a key-like motion, placing something into a virtual box, or flattening code into the desk to signify a foundation for future work.

For pushing, one participant mentioned an emotional aspect to the action, saying, 'I think pushing should be very satisfying because you do it when you are done.' This led to ideas like throwing a basketball to represent the act of sending code to a server. The direction of pushing also aligned with the conceptualization of the server as a cloud, resulting in gestures like pushing code upwards with two hands. Pulling was imagined as the reverse action, pulling an update down from the sky. However, we noted a challenge: a basketball-style push would not work for pulling since the 'ball' would not return. This prompted the idea of 'fetching' the ball from a central location where all branches are stored to check out a branch.

During these explorations, we realized that certain actions such as merging required selecting a specific branch. It became clear that we needed to think about a way to represent branches, but I wanted to keep the session focussed on the individual actions first, so the conversation was steered back to the actions of pushing and pulling.

The participants debated various pushing motions, such as an underhand swing from below or a push starting from the chest. The underhand swing felt more satisfying and natural since it starts closer to the keyboard. For pulling, the group experimented with various variants of the motion such as pulling with hands close together as if you are pulling a rope versus having the hands farther apart.

Git fetch, being similar to Git full, demanded a larger gesture to reflect its broader scope of retrieving all changes, not just those on a specific branch. Fetching differs from pulling in

that it retrieves all updates from all branches, whereas with pulling you retrieve and apply the actual changes, but only for your current branch. Ideas included a 'revealing' motion with one or both arms as if removing a cloak from an object, jumping up to peek over an imagined hedge, or leaning forward to look 'into' the desk. The front-end developer suggested tilting the head to look upwards to the ceiling, which aligned with the concept of updates coming from the cloud.

For merging, the group naturally gravitated towards gestures of bringing two hands together. Building on my insights from the first session, I discussed the nuance of merging into a base branch and the need to a select branch to merge into your current branch. This led to the idea of grabbing a branch from the sky and smashing it into another held branch, symbolizing the merge.

The session entered a new phase when a participant used a cardboard box that was present in the space to represent a branch. The physicality of this idea led to playful interactions, such as stacking two boxes together and stomping on it with one foot to merge branches.

This inspired the idea of branches as objects that could be moved between locations. For instance, checking out a branch could involve grabbing a box from a remote location and placing it on a desk. Having the branches you are working on your desk, you and your colleagues can all see what you are working on, could potentially change collaboration.

Committing could be visualized as slapping the box to 'lock in' the changes, while pushing involved throwing the box to a higher, 'remote' location. If this remote location is in a central location in the office, you create a shared workspace with your colleagues. To check out a branch, you would need to go to that location and bring the code to your own workspace.

To prompt deeper discussion, I took the the shape of the box in question. I suggested that perhaps a *line* might better represent a branch, as it aligns with how branches are typically visualized in graphical Git interfaces. A line reflects the sequential nature of commits. However, participants pointed out that while such visualizations exist, they are not central to their day-to-day interaction with Git. Instead, the graphical history of branches is primarily used as a reference, particularly when troubleshooting issues or examining past work.

When I introduced the metaphor of a tree, thinking it might align with the branching structure of Git—the participants also did not connect with it. They explained that their work did not feel 'tree-based' in nature. For them, the concept of a tree was primarily used for history tracking, not for their daily tasks. While they acknowledged that viewing a branch's history is sometimes necessary, they described it as a distinct, purposeful action rather than an ongoing need. One participant suggested that opening the 'box' could provide a way to access the commit history inside, an idea that aligned more closely with their workflow.

This exploration led to yet another metaphor: imagining each branch as a thread hang-

ing from the ceiling. By pulling a thread, you could bring it into your workspace to work on it. Initially, the participants were not particularly enthusiastic about this idea. However, later in the discussion, a back-end developer revisited the concept, acknowledging that it made more sense technically than a box, as it reflected the linear and hierarchical structure of branches. The front-end developer, however disagreed, stating 'this is not how I see it.'

One participant then introduced the concept of a *Rosary*, a chain of beads used in Christian devotional practices, where every bead signifies a step in a prayer. In this metaphor, the chain itself could represent the branch, while the beads could symbolize individual commits. This idea resonated with an earlier concept I had explored during a previous bodystorming session. We also explored how branches could grow in size as commits were added, representing workload. For example, the box could grow in size, or in case of the chain, it could get longer.

At the end of the session, I asked how it might integrate into the bigger picture of working as a developer. Many workflows in software development revolve around issues, which are essentially descriptions of a feature or part of a feature that developers are tasked with implementing. Participants highlighted that while not every team requires creating a branch for every issue, certain workflows like the one used by the front-end team at this company, do make such an approach logical and effective. However, the participants noted that adopting an issue-per-branch approach is not inherently problematic; it could even become a standardized workflow if aligned with the team's goals and processes. They recognized that systems like the one we were discussing could become a valuable tool for team collaboration in software development.

One suggestion that emerged was the potential benefit of labelling branches with the corresponding issues to provide additional clarity for teams. This could take the form of virtual sticky notes attached to branches, offering a quick and intuitive way to track progress and context. This would enhance the ability to associate work with specific issues, particularly in collaborative environments.

Towards the end of the discussion, we explored the broader implications of such a system, particularly in the context of remote work. While not the original scope of this research, this led to envisioning a virtual reality workspace inspired by existing collaborative tools. In this imagined system, developers could work within a spatial Git environment that would foster a more social and interactive experience. For example, team members could see one another represented in the virtual space, along with the branches and tasks they are actively working on. Such a system could visually and spatially convey progress, creating a sense of presence and community even in distributed teams.

This concept resonated with the participants, sparking enthusiasm as they imagined the potential for a more tangible and social way of collaborating on software. By blending spatial interaction with version control systems, such a VR workspace could fundamentally change how (remote) teams collaborate and engage with their work. Table C.2: Results of second bodystorming session for Spatial Git

ID

Action	Description	
1	Push	Two-handed pushing motion forward, starting from torso
2	Push	Two-handed pushing motion upward, starting from torso
3	Push	One-handed swipe motion to the side
4	Commit	With two hands grabbing on, placing on a 'shelf', writing a commit message on it
5	Commit	Two hands, forming a square with thumb and index finger, creat- ing a 'snapshot' of the moment. Placing this snapshot on a desk and writing on it
6	Commit	Grabbing motion with one hand, placing it to the side on desk
7	Commit	One or two-handed pushing motion, pushing through the screen
8	Pull	Jumping upwards, grabbing on with two hands and pulling down
9	Merge	One hand making a collecting movement, as if pulling a collection of items towards the body
10	Merge	Bringing both hands together, starting from the outside in
11	Merge	Bringing both hands together, starting from the outside in, but feeling resistance
12	Merge	Bringing both hands together, starting from the outside in, feeling resistance. Stopping, and removing or adding things to this space between the hands
13	Pull	Sitting down, grabbing elements from the desk towards oneself with two hands
14	(Push+) Pull	One person, sitting down, pushing contents towards the display, another person pulling these contents from the display towards themselves, both with two hands
15	Pull	With two hands making a scooping motion from the bottom to- wards oneself
16	New branch	Creating tension towards oneself and raising one hand upwards
17	New branch	Grabbing upwards and making a firm movement towards the floor
18	New branch	Making a 'poof' motion with both hands; starting from a raised fist at shoulder height, bringing hands slightly outward and opening
19	New branch	them Making a grabbing motion from a certain point towards oneself, as to grab something out of a 'stream'

<sup>0</sup>A small mistake was made in the order the digital sticky notes were filled in, causing disturbance in numbering

# Appendix D Skilled text manipulation sketches

#### D.0.1 Session 1

The first bodystorming session for *Skilled Text Manipulation* was executed with three persons, including the researcher. One participant has a background in Industrial Design and the other has a background in ecology. At the start of this session, I began by establishing some foundational rules: typing is still conducted using a keyboard and I conceptualized text as being on a virtual page that exists in front of the user,

The session started with creating a list of the most important types of interactions we have with digital text. This list included: selecting, cutting, copying, pasting, finding/replacing, removing, inserting and accepting autocorrect suggestions. After this, we had an open exploration of movements. After this initial open exploration, we ran through all the different operations one for one.

To explain the concepts effectively, we utilized text from posters present in the room. This approach proved to be quite effective, as it allowed participants to engage with familiar, tangible content while discussing abstract ideas. However, as the session progressed, we all gathered a feeling of how a digital page would look like, reducing the reliance on pointing to the posters.

We began with methods of text selection and noted that there is no direct analogy for this process in non-computer environments. We also explored how subsequent actions like cutting, copying, and pasting are influenced by the mechanics of selection. Participants consistently began movements for cutting and copying with their hands spaced apart, as this was the position the hands would be in after selecting text.

Similar to the bodystorms of *Spatial Git*, language seemed to play a role in shaping the gestures that were ideated. For example, an idea for a cutting gesture involved snapping the fingers together. This concept may have been subconsciously influenced by the Dutch language, where the term for cutting ('knippen') is also used to describe snapping fingers ('met je vingers knippen').

Interestingly, many of the movements were accompanied by verbal sounds made by

participants. This raises questions about whether these sounds could add an extra layer of definition or emphasis, helping participants conceptualize how their gestures might interact with the virtual text interface. One participant also noted that different movement styles might suit different individuals or moods. While some people might prefer bold, expansive gestures, others might favour more subtle, precise movements.

A significant realization was that selecting text and performing an action (such as copying or cutting) did not necessarily needed to be distinct steps. Instead, they could be integrated into a single, fluid motion. This concept opens up possibilities for more seamless and intuitive interactions.

We discussed the challenge of precision when selecting text at various levels—character, word, or paragraph. A potential solution involved using the distance between the hand and the eyes to control sensitivity. When the hand is closer to the eyes, movements appear faster relative to the background, allowing for finer control over smaller areas of text. Conversely, when the hand is farther away, larger areas could be selected with broader movements. This idea evolved into a dynamic mechanic where the distance of the hand could influence the zoom level of the virtual page. This approach could engage the body in a sensorimotor loop where hand movement is mapped to what you see.

Implementing this mechanic could also change how users navigate documents. For instance, when copying a word and placing it elsewhere, the ability to adjust zoom levels and control sensitivity in real time could enhance efficiency and fluidity.

<b>ID</b> 1	Action Selecting	<b>Gesture</b> Pointing and making a touching motion in the air with one finger, moving this finger and making a touching motion again	<b>Discussion/Motivation</b> It is nice to define a be- ginning and end of the action.
2	Selecting	Short chop with a closed hand in the air, then moving the other closed hand to the desired place relative to the first hand, making a short chop with that hand	You want to drag some- thing apart.
3	Cutting	Snapping the fingers, raised hands next to the shoulders	The sound of the fingers and the feeling match the idea of cutting.
4	Cutting	Making a chopping motion with both hands forward	"As if you cut it from the page."
5	Cutting	Clapping the hands together	"The clapping feels nice."
6	Copying	Making a grabbing motion with both hands and bringing hands towards the self	
7	Copying	Making a chopping motion with both hands backward (towards the self)	
8	Pasting	Making a shoving or throwing motion with two hands	You throw your copied text onto the page.
9	Pasting	Similar to 8, making a motion from the self with two hands starting closed and moving forward while hands are opened	
10	Copying	Making a stamping motion	Copying could feel like creating a stamp.
11	Pasting	Making the same stamping motion	If copying would be a stamp, pasting would be stamping that stamp.
12	Pasting	Making a wiping motion with one open palm, as if smearing something out	Pasting something "like applying glue on a page."
13	Selecting (+Copy- ing)	Same selecting motion as 2, then taking this selection and bringing it to the self by bringing the hands together and moving them towards the body	Realized that selecting does not have to be sep- arate from the action; could be done in one motion. (continued on next page)

Table D.1: First bodystorming session for skilled text manipulation

# (continued from previous page)

ID	Action	Gesture	Discussion/Motivation
14	Searching	Making an "OK" sign with the fingers, for	
		the eye to look through, moving this sign	
		to the eye.	
15	Submit	Making a brief nod with the head	
16	Deleting	Making a big diagonal slashing motion	
		with one hand	
17	Deleting	Making short small chopping motions	
		with one hand, horizontally	
18	Deleting	Making a medium-sized slashing motion	
		with one hand	
19	Inserting	Pointing with one finger towards a place	
		in the text	
20	Inserting	Starting with the hands together, pointing	
		towards a place in the text, then opening	
		the hands up	
## D.0.2 Session 2

The second bodystorm for *skilled text manipulation* was conducted together with one designer with a background in human-computer interaction. The same actions were explored as in the previous session. I also shared some of the insights gathered from the previous session, so that, rather than starting from scratch, we could build upon previous insights. However, to not influence the ideation itself, I did not share with what movements or gestures we came up in the previous session.

We started with the action of selecting text. Initially, we explored a pointing or highlighting motion, where the hand is dragged over the text to be selected. However, after further iteration, we refined the movement to involve creating a bracket shape with the hand and moving it over the desired text. This adaptation felt more natural and precise. During the discussion, I shared insights from the previous session, particularly the notion that selection might not need to be a distinct motion separate from performing an action. This idea encouraged us to think more fluidly about interactions.

We imagined cutting as simply grabbing the text from the page and bringing it toward the self. However, this introduced a challenge: after cutting, there needed to be a way to let go of the text, move to another location, and paste it. To resolve this, we introduced the concept of a temporary storage space next to the user, where cut text could be placed before pasting. The participant noted that this could be beneficial, as it creates awareness of what has been cut. Building on this, I suggested the possibility of a timeline of previous cuttings, which could serve as a useful reference.

Deleting text followed a similar logic. Instead of placing the grabbed text onto the clipboard, the user would throw it away. Within this paradigm, pasting became a straightforward reversal of cutting—grabbing a saved cutting from the stack and placing it back on the page.

However, conceptualizing copying proved to be more challenging. Unlike cutting and pasting, we could not find an immediate real-world analogy that felt entirely natural. We explored the idea that, instead of grabbing the text and pulling it toward the self, copying could resemble a stamping motion, either by pressing forward on the text or moving a flat hand over it. While we struggled to justify this with a logical analogy, it felt intuitive in practice.

For deleting words or letters, we experimented with a slashing motion of the hand, which felt intuitive. We also explored the idea of using a kicking motion with the leg to achieve the same effect. However, we noted that this might become tiring over time, making it less practical for frequent use.

Compared to the first session, we recorded fewer ideas, as we adopted a more critical perspective on the interactions. This session was more theoretical, involving in-depth discussions and analysis rather than purely physical exploration. Additionally, we reflected on the difficulty of incorporating the entire body into interactions. While legs felt useful for movement, they were less suited for performing precise actions, whereas hands and arms

naturally lent themselves to more interactive and intentional gestures.

Table D.2: Second bodystorming session for skilled text manipulation

ID	Action	Gesture	Discussion/Motivation
1	Selecting	Making a C shape with index and thumb and dragging that through space	Makes sense if it works like the mouse does
2	Cutting	Selecting start point with one hand, end point with another, grabbing towards the body	
3	Pasting	Grabbing with two hands text that was previously cut, pressing it in place.	
4	Copying	Wiping with flat hands over 'page', as to make a stamp	It feels like making an imprint
5	Backspace	Wiping with a vertical hand, as if moving some- thing away	
6	Backspace	Kicking something away with one foot to the side	
7	Inserting	Two hands together, moving them forward as if dividing two things	
8	Inserting	Making a chopping motion downward, with two hands flat together.	

## Appendix E Evaluation questions

Note: in these semi-structured evaluations, not every question was asked to each participant. Some questions were not asked explicitly, but in another form.

- Do you think you could get good at using this system over time?
- What would be your biggest irritation factor when using this system?
- Do you think this system adds value to your workflow? If so, in what way?
- Does this system improve the way you currently use Git?
- Could this system replace current tools like project boards or Git GUIs?
- How does this fit with your way of working?
- How do you think this would change the way you collaborate with colleagues?
- Would this system make it easier to understand what others are working on?
- Do you think this would support you in becoming a better developer?
- Do you think this system aligns with your professional identity as a developer?
- Would a tree-based view (vs. separate branches) make more sense to you?
- Does this system make you move more, and how do you feel about that?
- Do you see yourself using this system in a solo project or only in a team context?

## Use of AI

During the preparation of this work the author used Google Gemini and ChatGPT in order to improve grammar and structure of certain sentences that were written by the author himself. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the work. This disclaimer is in accordance to University of Twente regulations as of starting this thesis [61]

An example prompt supplied to Google Gemini is:

Improve this sentence: The immersive nature and the ability to offer an embodied experience of AR is a distinctive quality. This opens up a wealth of possibilities for novel interactions, utilizing a much wider range of motions and support new types of visualisations that make use of all three dimensions, the space around us, and our body.

The output of the system was:

"The immersive and embodied nature of augmented reality (AR) is a distinctive quality, opening up a wealth of possibilities for novel interactions. AR leverages a wider range of motions and supports new types of visualizations that utilize all three dimensions, the space around us, and our bodies."

After reviewing and editing the content:

The immersive and embodied nature of augmented reality opens up a wealth of possibilities for novel interactions, utilizing a wider range of motions and supporting new types of interactions that leverage all three dimensions, the space around us, and our bodies.

Another example prompt:

I don't think premise is the correct word in this sentence. What other word should I use here? This paper continues on the premise of the 2007 paper by Djajadiningrat et al. [13]. In this paper, the authors argue that there should be more attention

given to exploiting users' potential for skilled actions in HCI instead of making user actions as simple as possible. Would argument be correct?

The output of the system was:

Yes, "argument" would be a more appropriate word choice in this context. "Premise" suggests a foundational assumption, while "argument" better captures the authors' stance and the main point they are putting forth. Here's the revised sentence: "This paper continues on the argument of the 2007 paper by Djajadiningrat et al. [13]. In this paper, the authors argue that there should be more attention given to exploiting users' potential for skilled actions in HCI instead of making user actions as simple as possible.

After reviewing and editing the content:

My proposal builds on the argument of the 2007 paper by Djajadiningrat et al. [13]. In this paper, the authors argue that there should be more attention given to leveraging users potential for skilled actions in HCI, instead of making user actions as simple as possible.