Dynamic Landscape Sensations

exploring a design method for interactive landscape experiences

& one prototype design for island 'Tiengemeten'

Roel Theunissen
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In fulfilment of the requirements
for the Master of Science degree
in landscape architecture at
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“As our tactile reality gradually merges with a digital one,

technology is rendered more biological to the point where we make the landscape and the landscape makes us.”

Daan Roosegaarde

Preface

Humans exist to evolve. We explore the possibilities of our world in order to improve our living conditions and our general well-being. We are tool builders. Hunting gear, the alphabet, electricity; examples that changed our world and, in consequence, changed us.

The early 1940's saw the introduction computer technology, a tool that over the course of but half a century has dramatically changed the ways in which we work, communicate, and spend our leisure. And because this technology is only becoming smaller and more powerful, new possibilities for its use continue to emerge.

Being a landscape architecture student with a deep fascination for these possibilities it felt only natural to take this as a point of departure. What could be more exciting and challenging than merging cold, hard and rational technology with our soft, elusive and multisensory landscape? The result: a design method that utilizes technology for the creation of immersive interactive landscape experiences.

The road that led to this final product has not been without problems, and included many more bumps and turns than I could have expected. In hindsight it would have been senseable to have opted for a destination ‘closer to home’, but my fascination for the topic made me travel those extra miles.

When boarding on this journey, it was initially the frustration of *actually seeing* our everyday world become more and more technology-oriented, while the landscapes we inhabit seemingly stay the same old same old. Is it not the responsibility of landscape architects to explore the possibilities of embedding technology into our landscapes, as opposed to letting Google Glass engineers turn our rich, multisensory world into a mere medium upon which the ‘digital world’ is projected? Obviously, such a statement does not offer any frameworks upon which to construct a research. The formulation of what I was doing and where I was going became my biggest challenge.

As would become apparent, this challenge actually lasted till mere weeks before the finalisation of the thesis. Many times when confronted with the question of what it is that I was working on, I left the questioner behind in utter confusion. The shear sea of possibilities offered by technology appeared difficult to navigate, especially when you are new to its waters and only have but a hunch of what the destination is.

Fortunately, I had great guidance from many different people. Finalizing this thesis successfully would not have been possible without my supervisor Paul Roncken, whom I would like to thank for his support and sincere belief in the relevance of this thesis in both the scientific discourse and design practice. I would also like to thank my family and friends, in particular Diana, for her enthousiasm in the earliest phases of the project as well as her critical feedback in the last phase; Rob, for the many insightful discussions about this thesis and landscape architecture in general; Dirk, for his remarks on the final text; and lastly, Dominique, for broadening my creative horizon.

After many months of work the first fruit of my fascination for landscape and technology has taken shape. As we like to say in my family:

Het komt altijd goed.

Roel Theunissen
October 2013

Abstract

English

Keywords: landscape architecture, design method, dynamic landscape sensations, interactive landscape experience, computer-mediated interaction, pervasive computing

This thesis is an exploration of a design method for interactive landscape experiences. Due to increasingly smaller and more capable computer technology, the opportunity has arisen to embed computing into our environments with the purpose of making these environments able to interact with humans. Current and past literature, as well as design practice, tends to discuss and explore the possibilities of this development in urban and architectural contexts. This research is an alternative exploration of this development by focussing on the possibilities within the field of landscape architecture, combining the pervasive computing concept from the Human-Computer Interaction domain with a theory on landscape experience from the field of Environmental Psychology and Landscape Architecture, in order to develop a design method for interactive landscape experiences.

First, a literature study leads to a definition of pervasive computing and the identification of its components, enabling the use of this concept for the design of interactive environments. To understand how landscape architects can use these components in the design of such environments, the theory of affordances is reviewed and expanded to provide design tools. Secondly, a review of an existing theory on landscape experience reveals how landscape architects can design aiming for particular landscape experiences. Lastly, the design for interactive environments is then put into the perspective of design for landscape experience, resulting in a design method for interactive landscape experiences.

This research shows that the current theory on landscape experience provides the concept of *sensations* as a tool for the design for landscape experiences. The integration of pervasive computing in the design for landscape experiences produces the concept of *dynamic sensations*: sensory perceptible features of an environment that, enabled by a technological system, change through the course of an interaction between people and the environment. This research indicates that, in the design of interactive environments for landscape experiences, the design of *dynamic sensations* is the prime task of the landscape architect –along with the design of the environment (being the operators and signifiers of the interaction-possibilities) and the formulation of the interaction in which these sensations come about. The whole setting in which dynamic sensations take place create the opportunities for interactive experiences of landscape.

Dutch / Nederlands

Trefwoorden: landschaps-architectuur, ontwerpmethode, dynamische sensaties, interactieve landschapsbeleving, computer-gefaciliteerde interactie, pervasive computing

Deze scriptie is een verkenning van een ontwerpmethode voor interactieve landschapsbelevingen. Doordat computertechnologie alsmaar kleiner en krachtiger wordt is de mogelijkheid ontstaan om deze in onze omgevingen te integreren en daarmee interacties tussen mensen en omgeving te faciliteren. Bestaande literatuur, evenals de ontwerppraktijk, lijkt voornamelijk gericht op de discussie en verkenning van mogelijkheden in deze ontwikkeling in stedelijke en architectonische contexten. Dit onderzoek is een alternatieve verkenning van deze ontwikkeling door zich te richten op de toepassingsmogelijkheden in de landschapsarchitectuur, waarbij het pervasive computing concept uit het Mens-Computerinteractie domein wordt gecombineerd met een theorie over landschapsbeleving uit de Omgevingspsychologie en Landschapsarchitectuur, om te komen tot een ontwerpmethode voor interactieve landschapsbelevingen.

De eerste onderzoekstap is een literatuuronderzoek naar pervasive computing. Deze leidt tot een definitie van het concept en de identificatie van componenten, zodat het mogelijk wordt dit concept te gebruiken voor het ontwerp van interactieve omgevingen. Om te begrijpen hoe landschapsarchitecten deze componenten kunnen inzetten voor het ontwerp van deze omgevingen wordt de theorie van affordances uitgebreid, zodat de ontwerpgereedschappen die deze theorie levert niet enkel voor passieve maar ook voor interactieve omgevingen gebruikt kunnen worden. De tweede onderzoekstap toont doormiddel van een literatuur review aan hoe een bestaande theorie over landschapsbeleving landschapsarchitecten in staat stelt te ontwerpen voor een bepaalde gewenste landschapsbeleving. Uiteindelijk wordt het ontwerp voor interactieve omgevingen geïntegreerd in het ontwerp voor landschapsbeleving, om zo te komen tot een ontwerpmethode voor interactieve landschapsbelevingen.

Het onderzoekt toont aan dat de bestaande theorie over landschaps-beleving het concept *sensaties* oplevert als ontwerpmiddel voor landschaps-beleving. Door pervasive computing hierin te integreren ontstaat het concept *dynamische sensaties*: sensorisch waarneembare eigenschappen van een omgeving die veranderen in de interactie tussen mens en omgeving. Het ontwerp van deze dynamische sensaties lijkt tot de kerntaak van de landschapsarchitect te behoren, evenals het vormgeven van de omgeving en het formuleren van de interactie waarin deze sensaties ontstaan. Het geheel waarin de dynamische sensaties plaatsvinden creëert mogelijkheden voor een interactieve beleving van landschap.

Contents

INTRO

1 Research Introduction

We live in a world that is becoming progressively responsive, intelligent, and interactive in many different ways. With the unstoppable rise of computer technology, we have come to a point at which everyday objects are embedded with intelligent technology in order to make our lives more effortless and delightful.

In this increasingly interactive world the question rises whether the landscapes we inhabit can co-evolve into similar intelligent entities, or will remain the passive, analog spaces that they are today. This chapter poses this question upon a landscape architectural context and details the methodology with which the research was undertaken.

1.1 Research context

This thesis is undertaken as part of the Landscape Machine Lab, a design laboratory of the Landscape Architecture chair group at Wageningen University. Founded in 2012, its aim is to provide a discussion and development platform for landscape architecture students who are working on a master thesis related to the concept of 'landscape machines'. This participatory design lab attempts to create cohesion between the development of theories, methods and examples for the design of 'living' landscapes. These landscapes are studied from four different research angles relevant to the conceptual development of landscape machines, being landscape production, aesthetics, anthropology and narration. This thesis explores the possibilities of a technology-augmented 'living' landscapes from an experience-oriented perspective that is related to, but not inclusive of, research on landscape aesthetics and narration.

1.1.1 Shift towards an interactive world

Since the introduction of the first computer in the early 1940s, computer technology has been developing at a phenomenal and ever-increasing rate. Its introduction into our everyday lives since the late nineties has radically changed the way we work, communicate and spend our leisure. With computers becoming continously smaller, faster and smarter, we have found ourselves in a shift in which technology moves out beyond the desktop into the sites and situations of everyday life (Weiser 1996, Moran & Dourish 2001, McCullough 2006, Galloway 2008).

This shift towards a progressively responsive, intelligent, and interactive world is the result of *a human desire* to imbue physical objects and environments with computational capacities and networked data, in order to make life more effortless and delightful (Galloway 2008: 147). Various design disciplines are already engaging in the exploration of this desire, utilizing the new-found possibilities of state-of-the art technologies in many creative ways. For the moment, consumer product design and interactive art design seem to be taking the lead in this exploration –illustrated by three popular examples highlighted in box 1.1.

Examples of the shift towards interactivity BOX 1.1

Three exemplary products that illustrate the shift towards an interactive world are: the 'Jawbone Up' wristband (2011), one of the now many devices available that help us measure and manage our health effortlessly; the 'Nest Thermostat' (2011), a self-learning device that optimizes heating and cooling of homes; and lastly, art installation 'DUNE X' (2012), an artificial landscape that responds by lights and sounds to the behaviour of its visitors.

1.1.2 Landscape architectural perspective

Having acknowledged the fruition of a shift towards interactivity, the question rises how landscape architecture can move along in this shift. This question touches upon two issues:

1. The manner in which interactive computer technology is applied in a landscape setting.

Landscape architecture is concerned with giving form and substance to a physical space that is multisensory and dynamic, changing through the course of time (Koh 2013). As such, the first issue calls for an understanding of how interactive computer technology can be applied in this type of space.

2. A landscape-related use for computer-mediated interaction.

In a *landscape approach* to design it are the landscape processes and the human experience of landscape that the landscape architects designs for (Koh 2013). When interactive computer technologies are applied in a landscape architectural context, the purpose of the interaction should be in line with this landscape approach to design. Put differently, the purpose of the computer-interaction should fall within the area of expertise of landscape architecture.

Addressing these issues will help define (1) the framework in which this research will study the augmentation of landscapes with interactive technology and (2) the framework in which the research will explore a possible use of computer-mediated interaction. The first issue is addressed by introducing the concept of *pervasive computing,* a vision of how physical environments are augmented with interactive technology. The second issue is addressed by defining computer-mediated interaction as a tool for creating 'interactive' experiences of the physical (visually and tactilely perceptible) and ambient (perceptible through whichever one of the senses) landscape.

1.1.3 Pervasive computing: a concept of interactive environments

Research on interaction between people and computers are predominantly taking place in the field of Human-Computer Interaction. This research domain has been exlored for concepts that explain the augmentation of physical environments with interactive technology, which delivered concepts going by names such as *ubiquitous computing*, *context-aware computing* and *tangible computing*. These concepts appeared to be based upon a vision of post-desktop computing that was formulated by computer scientist Mark Weiser in 1988. This vision, henceforth referred to as *pervasive computing*, is a concept of computer-mediated interaction between people and environment, in which the emphasis is placed upon the dissappearance of the computer technology facilitating the interaction (Weiser 1996).

Because landscape architecture is concerned with the designing of environments and not with the design of computer systems, this deep embedding of technology and the emphasis on interaction with environments are what makes this concept relevant to the discipline. The relevance of pervasive computing to designers of physical environments in general is evidenced by its adoption in wide range of disciplines, including architecture (e.g. McCullough 2004) and urban planning (e.g. Shiode 2000).

Though pervasive computing is helpful in understanding how interactive technology could theoretically be embedded in physical environments, it does not quite explain how interaction works on the user-environment level and what it precisely is that landscape architects can design of these interactive environments. For these purposes we will use the *theory of affordances* by Gibson (1977); an ecological approach to the behaviour of humans, stating that the actions that people are able to perform with an object or environment are defined by its physical properties. By replacing 'actions' with 'interactions', it is hoped that this theory will provide design tools for the actual application of pervasive computing.

1.1.4 Landscape experience: a purpose for interaction

In her doctoral dissertation on pervasive computing, Galloway (2008) describes that computer-mediated interaction can make an object or environment more functional (see the Nest Thermostat in box 1.1), or create a new or more compelling experience the object or environment (see 'DUNE X' in box 1.1). This research will focus on the use of computer-mediated interaction as a tool to enable 'interactive' experiences of the physical and ambient landscape. As Koh's (2013) landscape approach states, the design for the human experience of landscape is one of the key tasks of landscape architecture. By focusing on the use of pervasive computing in the design for landscape experience, this research hopes to contribute to the design toolset of landscape architects.

In order to study the design for interactive landscape experiences, we need to understand how landscape architects can design for landscape experiences in general. There is a range of literature available that aims to aid in the design for landscape experience through concepts such as aesthetics and narration (e.g. Spirn 1998, Potteiger & Purinton 1998). Though however useful such literature may be, one can expect that its use in this research would complicate matters by involving abstract concepts like aesthetics and narration within this study. For this research, which is first and foremost focused on the study of the pervasive computing concept, it is arguable better to use a theory that can help explain the design for landscape experience as the design of actual physical and ambient features of the landscape. For this purpose we will use two theories that, through combination, will help design for landscape experiences in a very elementery manner. The first theory is by Jacobs (2006), who provided a comprehensive *theory of landscape experience* in his dissertation on the production of mindscapes. The second theory should help to translate theory into tools for design. This is the *theory of conceptual metaphor* by Lakoff & Johnson (1980).

Both theories are constructed upon the concept of embodied cognition, which comes from the philosophical method and school of phenomenology. This school, which began developing at the end of the nineteenth century, rejects the Cartesian separation between mind and body on which most traditional philosophical approaches are based. In place of the Cartesian model, phenomenology explores our experiences as embodied actors interacting in the world, participating in it and acting through it, in the absorbed and unreflective manner of normal experience. Embodiment cognition is at the centre of phenomenology, and states that all aspects of cognition are shaped by features of the body. In a paper demonstrating a mechanism for embodied cognition, Thelen (2001: 1) provides the following description of the concept:

"To say that cognition is embodied means that it arises from bodily interactions with the world. From this point of view, cognition depends on the kinds of experiences that come from having a body with particular perceptual and motor capacities that are inseparably linked and that together form the matrix within which memory, emotion, language, and all other aspects of life are meshed."

Because embodied cognition explains experiences through physical and ambient features, it is for designers of space an extraordinary useful concept –demonstrated by its influence in contemporary architectural theory triggered by the writings of Martin Heidegger. This is related to the theory of affordances introduced in the previous paragraph. Though introduced in 1977, before the formation of the embodied cognition concept, the theory shares similar perspective on human behaviour and is considered to be compatible with the phenomenological approach of embodied cognition (Hirose 2002).

1.2 Problem statement

According to Swaffield (2006), landscape architecture is considered to be concerned with design, while the core of design is theory. As such is the topic of this thesis interpreted: in order to get to design, theory first needs to be developed on *how* to design. Earlier we observed that we are in a shift in which the passive relationship between humans and physical objects and environments transforms into an interactive one. We raised the question of how landscape architecture can move along in this shift, and presented the concept of pervasive computing as a way of creating interactive landscape experiences. However, there is at this point in time there is no real understanding of how to design for interactive landscape experiences; the existing theory lacks a method that comprehensively describes how landscape architects can design for such experiences.

1.3 Research objective & questions

This research aims to explore a design method for interactive landscape experiences and, by doing so, contribute to the toolset available to landscape architects in design aiming for desired landscape experiences. This is hoped to be achieve by merging Weiser's pervasive computing concept with Jacobs' theory on landscape experience, illustrated in figure 1.1. The integration should lead to a comprehensive design method for computer-mediated, interactive landscape experiences. In line with the research objective, the main research question is formulated as follows:

→ By what method could landscape architects design for computer-mediated interactive landscape experiences?

There are three steps to be taken in order to come to a design method. The first is the formulation of a comprehensive definition of the pervasive computing concept, which existing literature is currently lacking. The second step is to

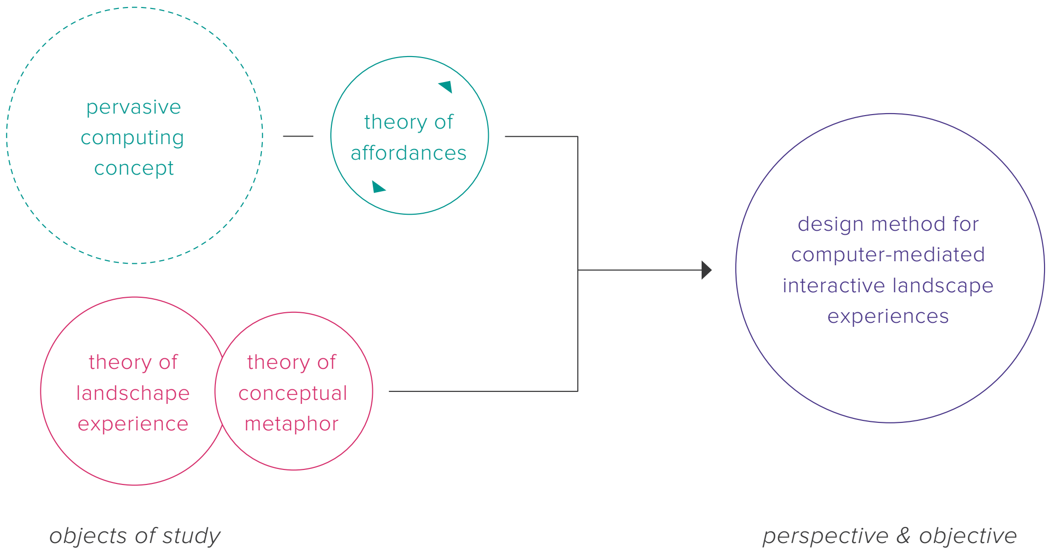

fig 1.1 Research framework

expand upon the theory of affordances so it can include 'interactions' and not just 'actions'. By doing so this theory could provide design tools for the application of pervasive computing in physical environments. The third and last step is the study of the theory of landscape experience and the theory of conceptual metaphor, in order to understand how landscape architects can design for landscape experiences. In order to achieve these objectives, three sets of sub-questions were formulated.

Developing theory on computer-mediated interactive environments

1a How does the pervasive computing concept help understand the design for computer-mediated interaction between people and an environment?

1b How does the theory of affordances by GIBSON (1977) help in understanding what landscape architects can design of computer-mediated interactions between people and an environment?

1c What design lessons can be derived from reference projects and expertise knowledge, and how do these relate to the concept of pervasive computing?

Current theory relevant to the design for landscape experience

2a How does the theory on landscape experience by JACOBS (2006) explain landscape experience and the design for landscape experience?

2b How does the theory of conceptual metaphor by LAKOFF & JOHNSON (1980) explain the design for landscape experience as the design of physical and ambient landscape features?

Linking pervasive computing with design for landscape experience

3 How does design for computer-mediated interactions between people and landscape relate to design for landscape experience?

According to the lexicon of garden and landscape architecture by Vroom (2006: 98), a design method is a systematic plan for the design of a particular thing and consists out of a series of successive phases, all involving a number of decisions based on deduction (the rational component) and on inductive jumps (the intuitive or creative component). In landscape architecture, two design methods prevail: the linear procedure and the cyclical procedure. The former is suited for simple design assignments, consisting out of a number of sequences; while the latter is suited for more complex assignments in which many more decisions need to be based on an assessment of interrelated factors.

What structure the design method for interactive landscape experiences will take is not yet evident at this point. It could be argumented that it likely will feature a cyclical procedure, involving various interrelated factors concerning both landscape experience and interaction. In any circumstance, it should thus be a systematic plan made up of a number of successive phases which describe how or with what tools, certain decisions regarding the design for interactive landscape experiences can be made. This plan will not be the sole truth, but *a truth*; one that has been uncovered in a (among others) specific societal and scientific context.

1.4 Methodology

The following paragraphs detail the methodology with which the research was undertaken. Each paragraphs discuss one of the three question sets in a chronological order.

1.4.1 Developing theory on computer-mediated interactive environments

To understand how the pervasive computing concept can be used to design computer-mediated interactions between people and environments, a definition of the pervasive computing concept and its components were needed. Papers of Weiser (1991, '93, '94, '96, and '99) were extensively studied and related to other prominent papers on the topic, including the doctoral dissertation by Galloway (2008), which offers a comprehensive overview of work on the pervasive computing concept. The study of reference projects functioned as a testing ground for the theoretical outcomes and helped to understand and translate imprecise concepts into a unifying, practical definition.

The following step was to expand upon the theory of affordances so can it includes 'interactions' as opposed to just 'actions'. This expansion is based upon a literature review of Gibson (1977), Hartson (2003) and Norman (2008). Throughout his research phase nine different reference projects were studied, along with writings and a lecture by experts on the design of interactive environments. This study of current practices created an understanding of the possibilities of interactive space and how to design for interactions between people and computer-mediated space. This knowledge was formulated in nine design lessons that link back to the definition of pervasive computing.

1.4.2 Current theory relevant to the design for landscape experience

The second set of sub-questions concerned the design for landscape experience. This part of the study consisted of a literature review of jacobs (2006) and Lakoff & Johnson (1980). The review of Jacobs theory on landscape

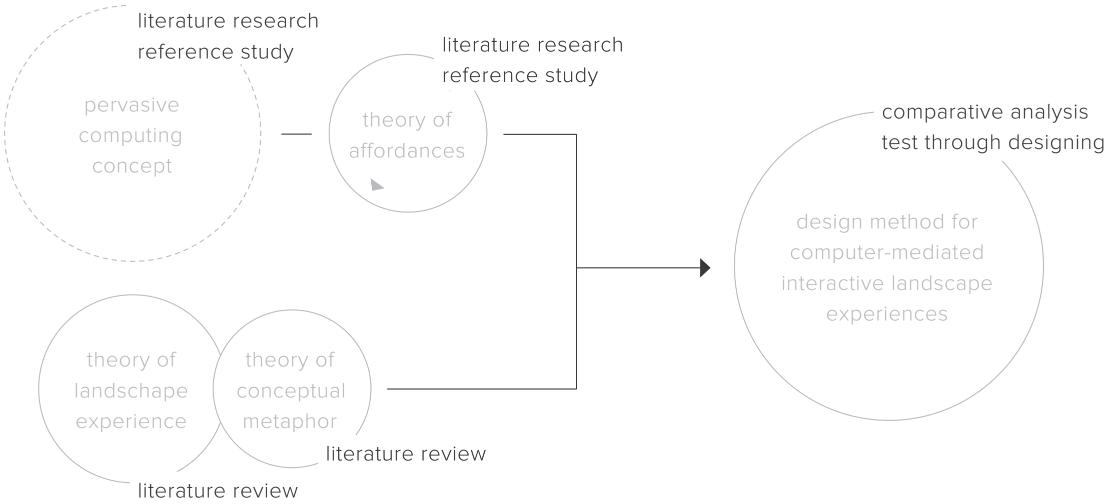

fig 1.2 Research methodology

experience provided an understanding of how landscape experiences are constructed and revealed what can be designed of these experiences. Lakoff & Johnson's theory was subsequently reviewed to identity how the design for landscape experiences translates to the design of landscape features

1.4.3 Linking pervasive computing with design for landscape experience

The third and last sub-questions concerned the integration of the design for interactive environments with the design for landscape experience. Through a comparative analysis the overlaps and similarities between the two objects of study were identified. This facilitated the development of a comprehensive design method for interactive landscape experiences. The validity of this method was tested through (paper) designs for the test case 'Tiengemeten', introduced in the following paragraph.

1.5 Test case

The design method resulting from the research is an hypothesis; built on literature research and reference studies and constructed using logical reasoning. To prove its validity it needs to be tested, which is done by actual design. The research required therefore a test case; a site and an accompanying design challenge that provide a design context.

Because the design method is focused on design for interactive landscape experiences, a number of selection criteria can be distinguished. The first criteria is that the site should be typical to the working field of landscape architecture. Though this could be an urban or rural area, with the former being the most obvious to implement interactive technologies, a natural area would provide the most interesting design challenge. If interactive technologies can be put to use here, it is more likely that it can be used elsewhere. As such, a natural area as test case would function as a litmus test for the design for interactive landscape experiences. The second criteria regards the design for landscape experience. Designing for experience implies a local (as opposed to regional) and leisure-oriented design challenge. This means that the site should be human in scale, provide possibilities for leisurely activities and be judged to lack attractive or interesting landscape experiences. The third and last criteria regards the design for landscape interaction. Because the designed interactive environment will operate in a context of 'passive' environments, its physical boundaries should be carefully delineated.

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These criteria have led to the selection of the island of Tiengemeten, South Holland (The Netherlands) as ideal test case. Tiengemeten is a nature reserve marketed by property holder Natuurmonumenten as a hiking paradise that offers free exploration of tidal nature in its infinite variety (Natuurmonumenten 2013). Taking in a position as designer, I would argue that Tiengemeten does however lack attractive and captivating landscape experiences –especially when taking into account the many people whom may have no particular relationship or bond with 'nature'. To create appealing and immersive interactive landscape experience on this island can considered to be a true design challenge.

As is apparent, Tiengemeten complies with the selection criteria. It is a natural and well-defined area, focused on use for leisure, but missing the landscape experiences that make leisurely activities attractive. For a more detailed description of Tiengemeten, see box 1.2.

About test case Tiengemeten BOX 1.2

Tiengemeten is an island in the Dutch province of South Holland, situated about an one-hours drive from the city of Rotterdam. It is approximately seven kilometres long (latitude) and two kilometres wide (longitude), shaped by the interplay between the rivers and the sea, and later (from the seventeenth century and onwards) also by men. The interplay between rivers and sea has been reduced significantly with the execution of the Deltaworks, stabilizing Tiengemeten's form.

The island was used for agricultural purposes ever since the first occupation by man. After Tiengemeten was flooded during the great North Sea flood (Watersnoodsramp) of 1953, the land was reformed into the large-scale and modern agricultural landscape by which many of the Dutch polders are characterised. In 1994 however, after four centuries of human struggle against water, the Dutch government designated the island as a nature development: tidal marsh ecology would replace neatly ordered farmlands. After years of preparation by the new owner Natuurmonumenten, the island was officially reclaimed as 'nature'. For this to happen, farmers were relocated, existing dykes were partially lowered, new embankments were constructed, roads were removed, and an artery creek was excavated. Tthe island is now a marshy pasture with trackless terrain, creeks, gullies and large populations of migrating birds.

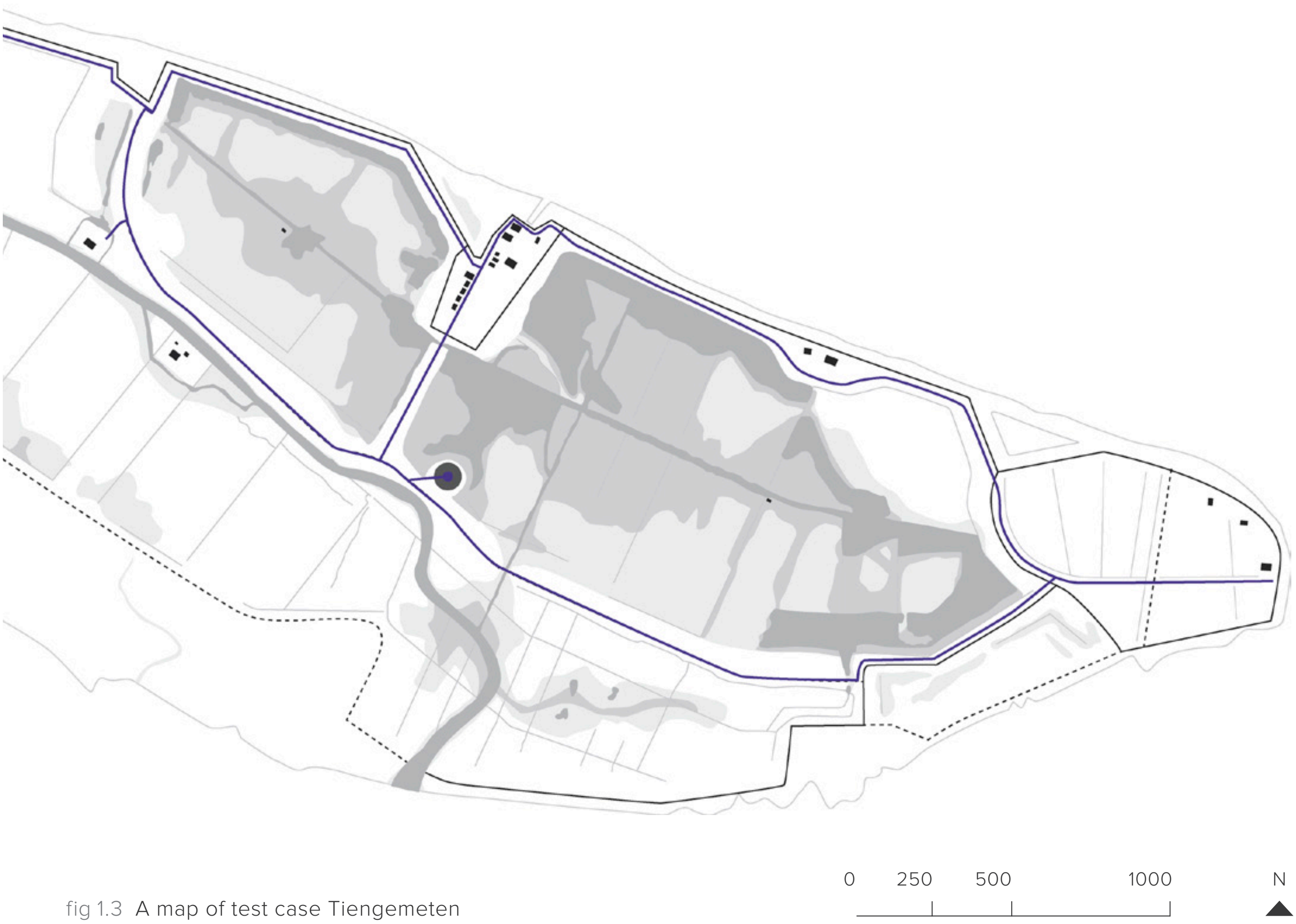

fig 1.3 A map of test case Tiengemeten

After a ten-minute trip the ferry arrives at the island’s small harbour, functioning as point of entrance for visitors.

Upon entering the nature reserve, the visitor is provided with an overview of the island from atop one of the dykes.

View from atop barn ruins, looking south-east towards an abandoned and overgrown farmyard.

View from near the water inlet of the 'Weelde' marshes, looking southwards.

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PART I

Interactive Environments

2 Developing Theory on Interactive Environments

As presented in the introduction, the key subject of study is computer-mediated interaction between people and environments. To understand how this type of interaction is possible, the concept of *pervasive computing* from the Human-Computer Interaction domain is drawn in.

Existing literature does however lack a detailed and comprehensive description of this concept. This chapter presents a study of this literature, leading to a definition of pervasive computing and the identification of its various components. By doing so we can formulate questions that are of relevance in the design of interactive environments according to the pervasive computing concept.

2.1 Introduction to pervasive computing

To understand pervasive computing means to understand how environments can become interactive entities means to understand *pervasive computing*, a concept rooted in the field of human-computer interaction but since its introduction adopted in a range of scientific disciplines such as sociology and architecture. This paragraph serves as an introduction to pervasive computing, starting at it origin.

In 1988, during his time as Chief Technologist of the Xerox Palo Alto Research Center (PARC), Mark Weiser coined the phrase 'ubiquitous computing'. Both alone and with PARC Director and Chief Scientist John Seely Brown, Weiser wrote some of the earliest papers on the subject, largely defining and sketching out its major concerns. In a paper titled 'The coming age of calm technology', Weiser & Brown (1996) defined *ubiquitous computing* –synonymous with *pervasive computing*– as the third wave of significant technological change that fundamentally alters the place of computer technology in our lives.

Since the first general purpose electronic computer in the early '40s two important trends have developed in the relationship between man and machine: the *mainframe relationship*, in which many users share a computer; and the *personal computer relationship*, in which there is one computer and one user. With the introduction of computer networks and the global internet, we are carried through an era of widespread distributed computing towards the relationship of *pervasive computing*, in which computers are deeply embedded in physical locations and objects.

In his seminal article, 'The Computer for the 21st Century', Weiser (1991: 94) argued that *'the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it'*. He envisions a world where hundreds of invisible computers are embedded in objects and environments. In effect, people would not so much interact with these computers, but with the objects or environments in which they are embedded. Weiser (1994: 8) elaborated upon the aesthetics of this vision in 'The World is not a Desktop':

The clock, and the clockwork machine, are the metaphors of the past several hundred years of technology. Invisible technology needs a metaphor that reminds us of the value of invisibility. I propose childhood: playful, a building of foundations, constant learning, a bit mysterious and quickly forgotten by adults. Our computers should be like our childhood: an invisible foundation that is quickly forgotten but always with us, and effortlessly used throughout our lives.

fig 2.1 Paradigms of the computer and the computer interface.

From the perspective of design, this type of computing was novel because Weiser's inspiration came from the social and cultural realms as opposed to from the technological (WEISER 1993). He began with an explicit interest in the role of computers in everyday life and a desire to build computers that did not interfere with our everyday activities (WEISER 1994: 7):

A good tool is an invisible tool. By invisible, I mean that the tool does not intrude on your consciousness; you focus on the task, not the tool. Eyeglasses are a good tool – you look at the world, not the eyeglasses. The blind man tapping the cane feels the street, not the cane.

Put differently, *'invisible technology'* is equally about the physical disappearance of computing as it is about the mental disappearance, yet without losing the capability of moving from the periphery of our attention towards its centre (WEISER ET AL. 1996).

To describe this kind of technology, Weiser used the term 'ubiquitous computing'. Over the gradual development of the paradigm, others adopted the vision but used various other terms with each one emphasizing a slightly different quality of the 'invisible technology'. As MCCULLOUGH (2007: 384) discusses in his book 'Digital Ground: architecture, pervasive computing and environmental knowing', the terminology suggested by Weiser is problematic because 'ubiquitous' implies standardized, always on, and existing everywhere at the same time. In the context of this research, the often-used term pervasive computing seems more appropriate for its emphasis on physicality, existing in every fibre of places and objects. This term is widely accepted in the field of human-computer interaction and used as a synonym for ubiquitous computing, as it will be used here.

2.2 Defining pervasive computing

Though the preceding paragraph creates an understanding of what the pervasive computing concept entails, it lacks a precise definition. This problem arose in the process of studying reference projects (see chapter 4), where it appeared to be impossible to precisely explain why a project can or cannot be classified as 'pervasive computing'. Papers from Weiser nor other literature provide a comprehensive definition of the concept. Though Weiser, as godfather of the concept, does obviously discuss the features, they remain largely vague, are only shortly touched upon, and used with inconsequent terminology.

In order to understand how we can design for interactive environments, this paragraph provides a detailed description of what precisely defines pervasive computing. For this to be possible papers of Weiser (1991, '93, '94, '96, and '99) were extensively studied. Findings were related to other prominent papers on the topic, including the doctoral dissertation titled 'A Brief History on the Future of Urban Computing and Locative Media' by Galloway (2008), which offers a comprehensive overview of work on the pervasive computing paradigm. Reference studies (see chapter 4 *Current Practice*) functioned as a testing ground for the strongly theoretical outcomes and helped to understand and translate imprecise concepts into a unifying, practical definition, which is as follows:

Pervasive computing is a concept of computer-mediated interaction between people and environments. This *interaction* is facilitated by a perceptive, interpretive and reactive *technological system*, sited and situated in a specific *context of use*, in which the system's *interface* is embedded physically, procedurally, and socially.

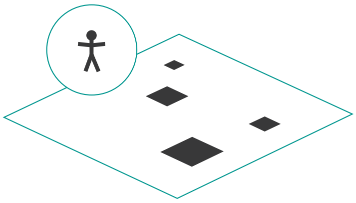
This definition consists of four components, each of which is described in the following paragraphs along with their relevance to the design of interactive environments. Before moving on to a detailed specification of these components it is helpful to briefly illustrate them through comparison with familiar concepts.

2.3 Components of pervasive computing

To augment environments with pervasive computing can be described as giving them human capabilities, being to perceive (the senses), think (the brain) and act (the body). These capabilities form the *technological system*, built from computer hardware and software that transforms otherwise passive environments into interactive environments. Because interactions take place in a specific site and situation, the system's hardware and software needs to be custom tailored in order to provide interaction possibilities that fit in this *context of use*. Finally, the interaction can only occur because there is an *interface* with which the user provides input for the technological system. Like conventional computer systems, pervasive computers have an interface with which the user provides input, but whereas the former has a mouse and a keyboard, the latter needs to derive its user input in more subtle, 'invisible' ways. The pervasive computer's interface consists therefore of physical features and the user's body itself, in effect turning space and human behaviour into the interface.

The following paragraphs serve to explain the four components of interactive environements, starting with *context of use,* which provides the basis for the formulation of an *interaction*. Following these components we move to the *interface* and end with the component that is the least relatable to landscape architecture, the *technological system*. The specification of all components facilitates the development of general design questions. These questions are listed at the end of each paragraph.

2.2.1 Context of use



The first aspect that defines pervasive computer is its groundedness in *context of use*, made apparent in literature where the term 'context-aware computing' is synonymously used with 'pervasive computing' (e.g. by Moran, Bellotti & Edwards, and Galloway). The *context of use* comprises site and situation, as McCullough (2006: 26) touches upon when phrasing that pervasive computing *"moves out beyond the desktop into the sites and situations of everyday life."* In order to move computing off of the desktop, it must not only have a comprehension of physical and ambient features of a space, being the *site* (Brummit 1999), but also of the constraining tasks and communications in this space, being the *situation* (McCullough 2007). The site to which Brummit refers is a finite physical space, due to the physicality of the computer's hardware; the technology is either present in a particular area or it is not. There can however be an fictitious gradient, in which the interaction has a *centre*, where the application is in full use, and *periphery*, in which the interaction seems to fade in or out (Weiser 1996).

Whereas *site* is used to define the physical and ambient features of a space, *situation* is used to describe the type of space and the elementary actions in which its users are engaged (McCullough 2007). These concepts can be illustrated through a simple example; when designing an interaction at an street intersection, *site* is the combination of sidewalks, a crosswalk and traffic lights, whereas *situation* is an infrastructural public space where users wait on opposites sides of a demarcated space for the traffic lights to turn green and cross this demarcated space.

It is evident that the *context of use* concerns both the technological aspect of pervasive computing and user experience. In order to achieve 'invisibility', as envisioned by Weiser, the application must relate to both the *site* and the *situation* in which it is placed.

Design relevance

Having studied the notion of *context of use* it can be concluded that *site* and *situation* provide the possible purposes of an interaction, as well as the pool of physical and ambient features from which the interaction can be constructed. Thus when designing for interactive environments according to the pervasive computing concept, the following two questions are of importance:

- Of what physical and ambient features does the *site* consist?
- Of what type of space and actions does the *situation* consist?

Now we understand that interactions take place and are designed for a specific context, we aim our focus glass on the interaction itself.

2.2.2 The interaction

As explained earlier, pervasive computing is fundamentally about a particular way of interaction between people and environments. Interaction is not merely a feature of pervasive computing, it is the ethical aim set out in the pervasive computing paradigm. The interactivity should improve or create new functionality and/or experience, while the technological system that facilitates it

What is (computer-mediated) interaction? BOX 2.1

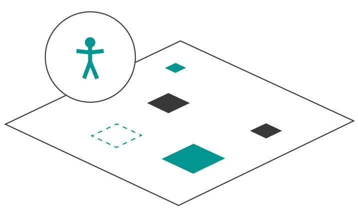
In many situations where a relationship between people, objects, or even non-physical elements is described, things are said to 'interact'. This misuse of the term leads to confusion and false claims of interactivity. The word *interaction* implies deliberation over the exchange of messages; a message sent is merely transmittal (action), a message sent back becomes two-way communication (reaction), and only when the message sent back is affected by the message received does interaction occur (McCullough 2007: 385). Put differently, a reaction is a monologue and an interaction a dialogue. This is translated to computer-mediated interaction by McCullough (2004: 20):

> *"Only when technology makes deliberative and variable response to each in a series of exchanges is it at all interactive."*

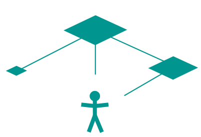
PURPOSE

disappears from view (Weiser 1996, 1999; Galloway 2004, 2008). Interaction in the pervasive computing concept thus has a functional and/or experiential *purpose*. Knowing this, the question rises whereof interactive environments exist.

Oosterhuis (in Garcia 2007: 61) describes interactive environments as being composed of elements and an interaction relationship. According to him the design of interactivity is the art of building a relationship between elements in the first place, and building a relationship between people and these elements in the second place. The *elements* to which Oosterhuis refers are the combined physical (visually and tactilely perceptible) and ambient (perceptible through whichever one of the senses) features that make up the interaction, and can be either already existent or purposefully introduced. Building a *relationship* between these elements can be a process of logic as well as of creativity (Oosterhuis in Garcia 2007).



An example of a relationship between a physical and an ambient element could be to link a tree, physical, with the sound of leaves in the wind, ambient. Having created this relationship we can introduce the user in the equation; for example, when the user touches the tree, a sound of leaves in the wind is played. In order to make this relationship between user and sound *interactive*, a set of parameters is needed. This is discussed in paragraph 2.2.4 *Technological system*.



Design relevance

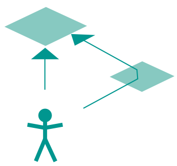
Having identified two ingredients for the design of interactive environments, being *elements* and *relationships*, we can pose four question regarding the design of interactive environments:

- For what *purpose*, functional and/or experiential, is the interaction?
- What are the *elements* of the interaction?
- What is the *relationship* between these elements?
- What is the *relationship* between these elements and the user?

Having laid out the basics of *interaction* and its *context of use*, we delve into *how* the user provides input for the interaction.

2.2.3 Interface

The *interface* encompasses all means by which the users provides input for the interactive environment. It consists of the users' body (e.g. voice, heartbeat), their movement through space, and their actions with interaction *elements* (e.g. touching). Would the *interface* not exist, the environment would not be able to interact with the user and merely proceed in a monologue directed towards the user.



Weiser (1996) explains that though pervasive computing requires user input it can still operate at the periphery of attention thanks to the deep physical, procedural and social embedding of the interface. *Physical embedding* is the use of peoples' body, their movement through space and their actions with elements as an interface. *Procedural embedding* is the use of behaviours common to the *context of use* as interface inputs. Lastly, *social embedding* is the use of associative design or design conventions in order to communicate to the user how he or she can actually provide input for the interaction.

Earlier, in paragraph 2.2 *Defining interactive space*, the example of a computer keyboard was given as well-known interface by which we provide input to a computer. In this example the keyboard itself is the physical interface; this interface is procedurally embedded in the activity of writing, and socially embedded (how we come to understand how to operate the keyboard) through learned design conventions and knowledge of the alphabet. Together these three aspects of the interface make it so that pervasive computing can be 'invisible', operating at the periphery of attention, while still thriving on the critically important user input.

Design relevance

Having clarified the concept of interface, we can now pose three design questions:

- What is the *physical interface* of the interaction?
- How is this interface *procedurally embedded* in the context of use?
- How is the interface *socially embedded* for ease of use?

2.2.4 Technological system

Central to the concept of pervasive computing is the *technological system*; the hardware and software infrastructures that make otherwise passive environments able to interact. Though the *technological system* is the enabler of interaction, it itself should dissolve into the background and be 'invisible' to its users. The system is therefore not the object of interaction but the *medium* for interaction between people and the augmented environment (Weiser et al. 1996), illustrated in figure 2.2 by the arrow between user and environment. Galloway (2004: 388) states that this system consists of three subsystems, with each being responsible for a specific task: the perceptive system, the interpretive system and the reactive system. She fails however to specify these

different subsystems, which is why other literature is used to provide further explanation.

The first part giving the technological system its sensory capabilities is the *perceptive system*, a collection of hardware (e.g. sensors) and software (e.g. data crawlers) technologies that work on extensive data acquisition. The hardware is focused on gathering data from the *context of use* –being the *interface* and *ambient data* (fig. 2.2)– while the software scours existing digital data outside of the physical domain (McCullough 2004: 76-115). The aggregated data forms the input for the *interpretive system*; the hardware and software that processes this data into meaningful information (Weiser et al. 1996) with the use of algorithms (Galloway 2008: 210). Algorithms are procedures or recipes for complex and automated calculation, data processing and reasoning, making pervasive computing capable of true interaction (see box 2.1). Roosegaarde (2010: 147) explains the features of an interaction algorithm as follows:

> *'Interaction occurs when I hit you in retaliation and we start fighting, building up a unique dialogue that consists of the behaviour evolving between both parties. Our installations' responses are determined by the overlapping of software patterns and their influence on each other.*

In his study on interactive architecture, Haque (2007: 61) describes this mutual influence of *software patterns* as dynamically determined *input criteria*. The software patterns by Roosegaarde and dynamic input criteria by Haque explain in a 'relatively' simple manner how a computing system can be classified as interactive.

This interactivity itself is embodied through the *reactive system*, the hardware technologies that transforms the commands of the interpretive system into physical or ambient changes of the environment (Galloway 2004, Weiser et al. 1996). The reactive system produces visual, tactile, auditory, olfactory and/or gustatory effects that can be registered by the human senses. It is this system that, in the process of interaction as a whole, takes up the actual communication with the users.

The different parts of the technological system do not need to all be residing in the environment with which the users interacts. While the reactive system needs to be physically integrated into the interactive environment, the perceptive system is embedded into the context of use in more general terms, and the interpretive system –being more like a traditional computer– is unrelated to the site and situation in whatever possible way.

Design relevance

This quick peek into the technical aspect serves to understand what is needed to make a technological system, and thus an environment, able to interact. These aspects lead to the following questions relevant to the design for interactive landscape experience:

- What *input* is gathered for the interaction by the perceptive system?
- What *(dynamic) input criteria* and *software patterns* are used by the interpretive system?
- What is the *physical* and/or *ambient output* of the reactive system?

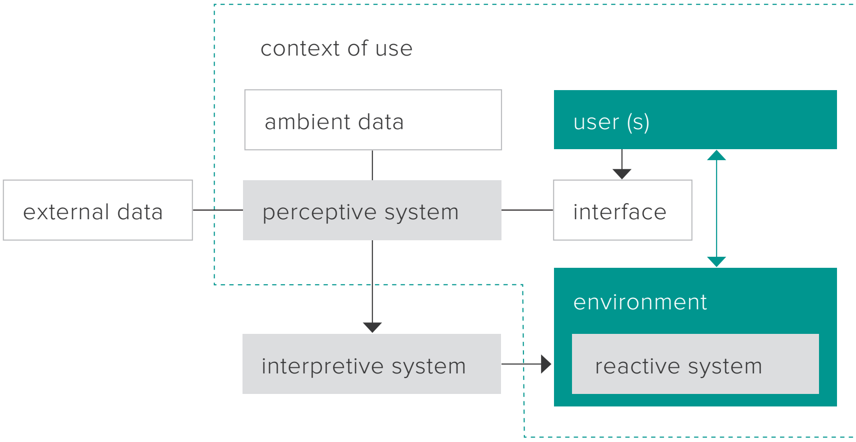


fig 2.2 Schematic representation of the pervasive computing concept as defined in this research.

2.3 Conclusion: framework for a design method

This chapter introduced a definition of pervasive computing (illustrated in figure 2.2) and identified the components of which computer-mediated interaction between people and environments are constructed (listed in figure 2.3). The definition of the pervasive computing concept and its components form a framework upon which a design method can be constructed. Summarized, the design for interactive environments should adhere to the following design criteria –directly derived from the definition presented in paragraph 2.2:

1. The interaction is sited and situated in a context of use.
2. The interface is embedded physically, procedurally and socially in this context of use.
3. The technological system is invisible or near-to invisible to the user.

These design criteria can be coupled back directly to the idea of 'invisibility' by Weiser, who considered that pervasive computing should be an 'invisible' tool for the mediation of interaction. Following these design criteria it should be possible to design tools that dissappear physically as well as mentally, yet without losing the capability of moving from the periphery of our attention towards its centre in order to operate as the mediator of interaction.

2.4 Addendum: critiques on pervasive computing

Having studied and defined the concept of pervasive computing, it is of use to know and understand the critiques on this concept in order to develop a more informed design method. The most comprehensive critique comes from Bell & Dourish (2006), who claim that instead of being a vision of the future, pervasive computing is already here, but far messier, obtrusive and branded as opposed to the clean, orderly and unobtrusive vision imagined by Weiser and

Interaction	
Purpose	The functional and/or experiential use of the interaction
Components	The physical and ambient features of the interactive environment
Relationships	The connections between the components of the interaction
Context of use	
Site	The sum of all physical and ambient features in which the interaction takes place
Situation	The type of space and the actions in which users are engaged
Interface	
Physical interface	The use of users' bodies, movements through space, and actions with objects as input
Procedural embedding	The use of behaviours common to the *context of use* as inputs
Social embedding	The use of associative design or design convention for ease-of-use of the interface
Technological system	
Perceptive system	The hard- and software that gathers data for the interaction
Interpretive system	The (dynamic) input criteria and software patterns
Reactive system	The physical and/or ambient outputs

fig 2.3 Overview of the in this research identified components of pervasive computing.

his following. Summarized, Bell and Dourish' objections are:

- pervasive computing's 'proximate future' places its achievements continually out of reach, while simultaneously blinding us to current practice.
- the framing of pervasive computing as something yet to be achieved allows researchers and technologists to absolve themselves for responsibilities for the present.
- the seamlessly interconnected world of future scenarios is at best a misleading vision and at worst a downright dangerous one.

Following up these objections, Bell and Dourish ask two questions: first, why is our vision of the future still the same as Weiser's; and second, why has this future not yet come to pass? They suggest two possibilities:

A. *'The proximate future is a future infinitely postponed; [...] when we are continually anticipating what happens next, and when our attention is continually directed over the horizon, then by definition ubiquitous computing is never about the here and now.'* (2006: 136)

B. *'Ubiquitous computing already has come to pass. Perhaps ubiquitous computing is already here, but took a form other than that which had been envisioned. Arguably our contemporary world, in which mobile computation and mobile telephony are central aspects [...] of everyday life, is already one of ubiquitous computing, albeit in unexpected form.'* (2006: 136)

The two researchers argue that the second scenario is most plausible (2006: 142):

‘The failure to notice the arrival of ubiquitous computing is rooted (at least in part) in the idea of seamless interoperation and homogeneity. The ubicomp world was meant to be clean and orderly; it turns out instead to be a messy one. Rather than being invisible or unobtrusive, ubicomp devices are highly present, visible, and branded’.

Being written before the introduction of wearable interactive technology such as the Jawbone Up (see box 1.1), the authors were eager to state that the pervasive computing paradigm had already come to pass. However, their claim that applications of pervasive computing might well be more visible and branded than expected is a very likely one, supported by among others Galloway (2008) and Müller, Alt & Michelis (2011).

What this might teach us is that interactive environments should be able to stand on their own and not be dependent of external technological systems or data flows. Additionally, Bell and Dourish put the invisibility which is so emphasized by Weiser into a more practical perspective; saying that the interactions do not have to merge seamlessly with their context of use but that they may, and likely will, stand out in this context as branded products.

3 Gathering Tools for Design

The previous chapter introduced a definition of the pervasive computing concept and identified the components of which interactive environments are constructed. However, it does not yet explain how the concept works on the user-environment level and what it precisely is that landscape architects can design of interactive environments.

This chapter discusses these issues with the help of the theory of affordances by Gibson (1977). Through a review and expansion of this theory we are able to not just gain insight into the workings of interactive environments in regard to the user, but also acquire tools with which landscape architects can use the components in the design of interactive environments. After having tackled both issues, the chapter is concluded with a basic design method.

3.1 Introduction to the theory of affordances

The theory of affordances by Gibson (1977) is an ecological approach to behaviour of humans and animals, stating that affordances are latent action-possibilities defined by the physical properties of an object or environment taken in reference to an actor. The perception of affordances happens through tactile, olfactory, auditory and optical sensory information. Gibson (1977) explains that an affordance does not change as the need of the actor changes because it is defined by what it is in terms of ecological physics (i.e. a description of the world relevant to the particular problems of psychology) instead of physical physics.

The theory of affordances provides the means to design an environment that better suits peoples' needs by helping the designer understand how an environment enables actions: *'Why has man changed the shapes and substances of his environments? To change what it affords him.'* (Gibson 1977: 130) This makes the theory of affordance relevant to landscape architecture, as supported by Maier & Fadel (2009) whom state that this theory allows design with intent –pointing to the designable features of the environment as facilitators of human behaviour– and Zeleke (2009) who argues that *'the subject matter of this theory is perception, or, in environmental design and architectural terms, form. Its key concerns are central to landscape architecture as well: form, meaning, experience, representation.'*

3.1.1 Traditional affordances

Figure 3.1 on the following page illustrates the concept of affordance and clarifies what there is to design of an object or environment in order to enable certain actions. The user is able to perceive using its senses and gathered knowledge, and can perform physical actions thanks to the capabilities provided by the body. Whereas the user is an active element in this equation, the object or environment is a passive one, being defined by static physical features (the form and substance, Gibson 1977) and static ambient features (the sensory appearance, Hartson 2003). The physical features of the object or environment relate to the user's capabilities. The physical action they afford a user is described as the *action-possibility* or the physical affordance (Hartson 2003). Action possibilities are always true. Cognitive affordances, the *perceived action-possibilities*, can however be either true or false (Hartson 2003). If an user perceives to be able to lift a rock that is in fact much heavier than its size and material appearance would suggest, the cognitive affordance is false. When

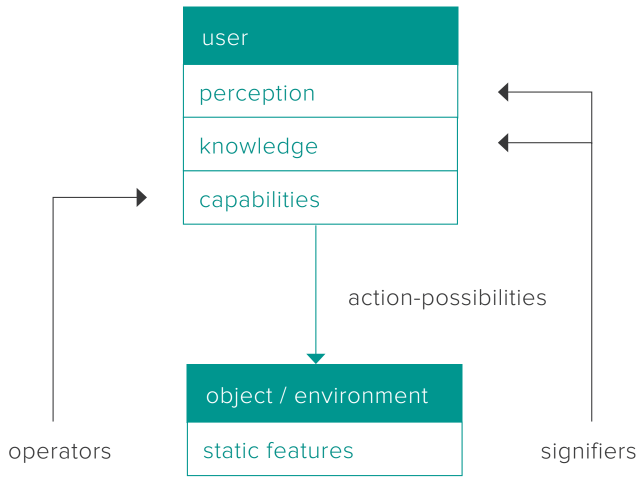


fig 3.1 A 'traditional' affordance as described by Gibson (1977), supplemented with the classifications of *operators* and *signifiers*.

the rock can be lifted but its size and material appearance suggest to the user that it cannot, the action-possibility is not perceived at all.

This brings us to the design for affordances. Strictly taken, an affordance cannot be designed because of its dependence on the user's perception and capabilities. In the equation of user and object or environment only the physical and ambient features are available to the designer. Being human him- or herself, the designer can however predict to an extend if these features will actually provide the proper physical and cognitive affordances. This designing for cognitive affordances is described by Norman (2008) as the design of *signifiers*: the specific ambient features that can facilitate the perception of an action-possibility. There seems to be no similar term available in literature for the specific physical features facilitating an action-possibility. For this, we introduce here the term *operators*. These are the two tools available to the designer to create objects or environments that can be used by people.

3.1.2 Introducing smart affordances

Having clarified how the theory of affordances provides tools for the design of 'traditional' objects and environments, the next step is to explain how this translates to the design of active ones. To take this step, the original theory by Gibson needs to be expanded upon in order to include not just passive but also active environments, as Weiser (1996: 4) had already suggested:

> *Our notion of technology in the periphery is related to the notion of affordances, due to Gibson (1977). An affordance is a relationship between an object in the world and the intentions, perceptions, and capabilities of a person. The side of a door that only pushes out affords this action by offering a flat push plate. The idea of affordance, powerful as it is, tends to describe the surface of a design. For us the term "affordance" does not reach far enough into the periphery where a design must be attuned to but not attended to.*

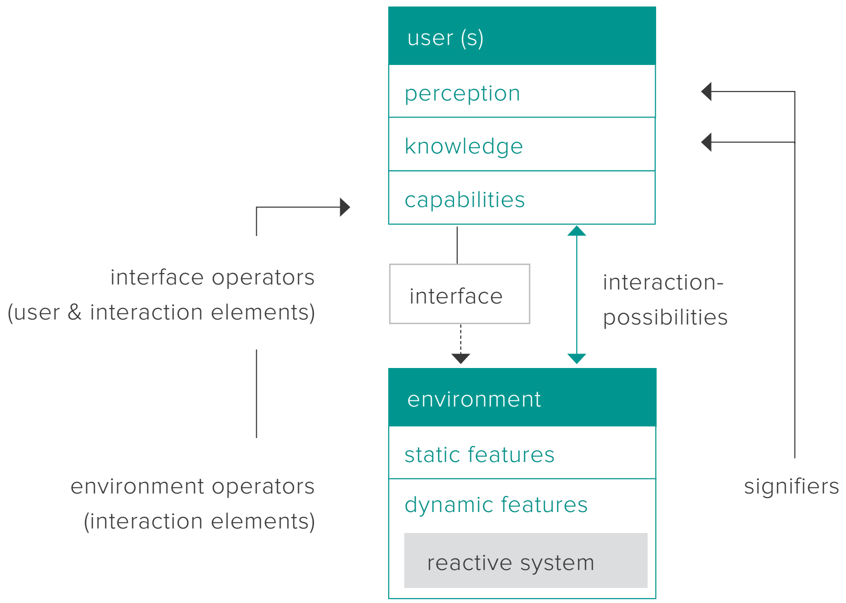


fig 3.2 A 'smart' affordance, offering interaction-possibilities as opposed to only action-possibilities.

The critique of Weiser on Gibson's focus on the surface of objects or environments is justified. More recent literature by Hartson and Norman as introduced in the previous paragraph is however more inclusive than the original work by Gibson, adding ambient features into the equation and leaving the problem of 'periphery' already partly resolved. It does however not yet explain how an active environment actually can provide not just action-possibilities, but *interaction-possibilities* for the user.

Taking the schematic figure used to illustrate the 'traditional' affordance, it is immediately apparent that a few things are different. In figure 3.2 the environment does not consist just of static physical and ambient features but also of *dynamic* physical and ambient features, enabled by the integration of a *reactive system*. Facilitated by the supporting *interpretive* and *perceptive systems*, the environment is transformed into a dynamic entity that does not only provide action-possibilities, but also interaction-possibilities.

Whereas the 'traditional' affordance has only one type of operator, the 'smart' affordance has two: the physical features facilitating the interaction-possibility from within the interactive environment (the *environment operators*); and the features facilitating the input for the interaction (the *interface operators*). The environment operators are both the static and dynamic features of the environment. These dynamic features are the interaction elements as defined in the previous chapter. The interface operators are the combination of the user and interaction elements. The *signifiers* of 'smart' affordances are both the dynamic features of the environment –the physical and ambient changes created by the reactive system– that are perceptible to the user, and (dependent of design) the features that enable the user to create an understanding of the relationships between the input actions and this output.

3.2 Perception of the interaction

This leads us to the following issue of design for computer-mediated interaction between people and environments. In 'smart affordances' the relationship between the user and the environment changes from being one-side (user acts with environment) to being two-sided (user interacts with environment). Because this interaction is, according to the pervasive computing concept, deeply embedded in the context of use, two questions arise concerning the perception of the interaction by the user:

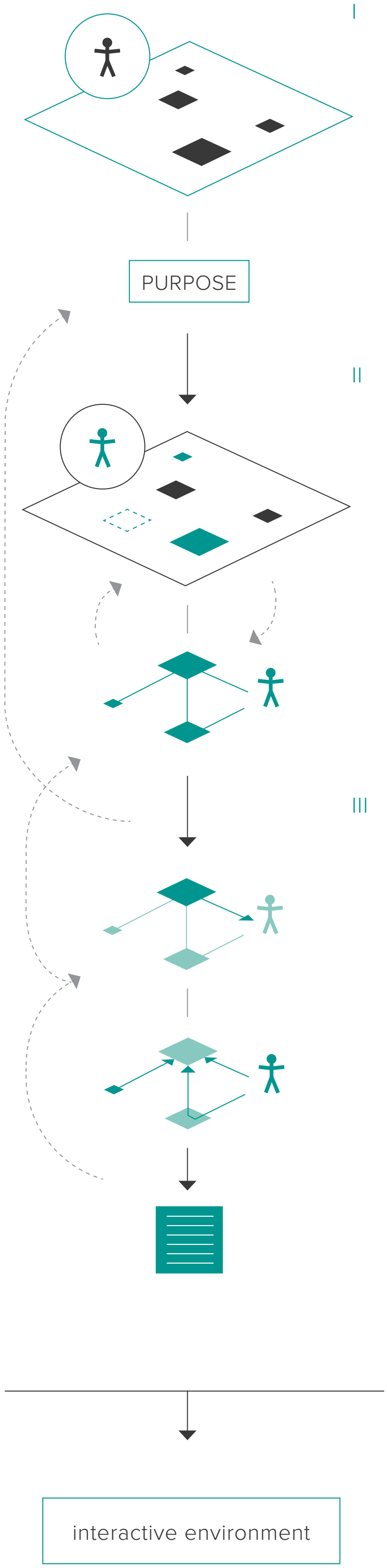
- Does the user need to be aware of the interaction-possibilities of the environment?
- Does the user need to understand the effect he or she has in the interaction?

These questions are fundamental in the design of interactive environments, because their answers determine the user's experience of the environment in general and the experience of the interaction in particular. They may also seem contradictory; how can you participate in an interaction without knowing? This can be illustrated by a simple example. Imagine you are in a space that changes itself, based on various inputs provided simply by your presence. In response to these changes you unconsciously change your behaviour. By doing so, you engage in an interaction with this space without being aware of it. In this example, the space does not provide signifiers in order for you to perceive the interaction-possibility. It is the task of the designer to determine whether the user needs to be aware of the interaction-possibilities and whether the user needs to understand the effect he or she has in the interaction. If the answer to one or both of the above questions is yes, the designer needs to create signifiers that communicate this to the user.

3.3 Conclusion: design for interactive environments

This chapter has provided an insight into the workings of interactive environments in regard to the user and defined tools with which designers can use the pervasive computing components in the design of interactive environments. With this knowledge we can formulate a basic method for the design of interactive environments.

Shown on the right page, this method consists of three phases: an analysis, an exploration of possibilities, and the design of the interaction. In the first phase the context of use is defined in order to formulate a purpose of the interaction. As Galloway (2008) writes, the purpose can be functional or experiential. The second phase serves to study the possibilities given by the context of use, taking elements of this context and creating relationships between them to explore how the interaction and its purpose can materialize. The third and last phase is the design of the interaction, which is both the design of the interactive environment and the design of the interface and technological system.



I Analysis

1 Define the *context of use* (the *site* and *situation*) in which the interaction is to take place.

2 Formulate the *purpose* of the interaction, suited to the context of use.

II Possibilities

3 Select from the context existing *elements* (users, physical features, and ambient features) and/or define new ones, that are associated with the purpose of the interaction.

4 Create *relationships* between these elements, giving the purpose of the interaction and the interaction itself its actual form.

III Design

5 Select the dynamic element in the interaction, formulate its output, and design the *environment operators* and the *signifiers*.

6 Formulate the input from elements (ambient data) and the interface, and design the *interface operators*.

7 Formulate (dynamic) *input criteria* and *software parameters*.

4 Lessons from Current Practices

The previous chapter provided an insight into the workings of interactive environments on a human-environment level. Based upon this insight it presented tools with which landscape architects can design interactive environments. This chapter serves as a verification of the applicability of this deduced knowledge through the analysis of two reference projects. Along with a study of writings and talks from experts on interactive environment design, the analysis leads to the formulation of nine design lessons.

4.1 Introduction to current practice

As supported by Bell & Dourish (2006) paragraph 2.4, interactive environments are beginning to emerge. Increasingly smaller computers are becoming capable of processing the vast amounts of data that is produced in the physical world, making the concept of pervasive computing feasible and fueling a new kind of design practice; *interactive environment design*. This new practice seems to be fuelled by design studios that create art-oriented, interactive installations and architectural spaces. Two well-known examples are Studio Roosegaarde, based in The Netherlands and China, and Local Projects, based in the United States. Although there is this variety of outdoor installation by these and other design studios in which pervasive computing is applied –such as *Braincoat* (EAR Studio, Diller Scofidio + Renfro, 2002) and *DUNE X* (Studio Roosegaarde, 2012)– substantial research on how pervasive computing can be applied in landscape architecture is still missing.

This is evidenced by the lack of available literature on this topic; a simple Google Scholar search with the keyword combination of 'landscape architecture' and 'pervasive computing' or 'ubiquitous computing' delivers 86 and 151 results (in October 2013) –in comparison, 'landscape architecture' brings up almost 120k hits. In addition, a quick glance learns that the larger share of the results is irrelevant for the understanding of design with pervasive computing in landscape architecture. This is partly due to how a search engine works, but equally due to the scope of the pervasive computing concept. Nonetheless, it is evident that interaction design as understood in pervasive computing is new to landscape architecture. So in order to better understand how this kind of interaction design works in practice, reference projects from outside of the discipline were studied. The analysis and the findings are presented in the following paragraphs.

4.2 Reference projects

Nine different reference projects were studied to understand how existing applications of pervasive computing work and to formulate design lessons from this knowledge. While selecting and studying these projects a fundamental problem arose, being that it was not quite possible to classify a project under pervasive computing or not with the help of current literature. This has led to the definition of pervasive computing as stated in paragraph 2.2. Four projects did not comply with this definition, leaving five suited candidates. Of these five, the two projects that are most relatable to landscape architecture are described in detail here. The others can be found in appendix II *Reference projects*.

Braincoat

In 2002 architecture office Diller Scofidio + Renfro cooperated with studio EAR for the Blur building, a project for the EXPO.02 in Neuchâtel, Switzerland. The building resembled a cloud built using artificially generated fog. As visitors entered the building nearly all of their visual and acoustical references were erased and instead replaced with a white foggy atmosphere and the white noise generated by the fog nozzles. The blur building itself was a circular steel platform with a thin spherical framework, hovering above the lake of Neuchâtel at a fair distance of the shore.

Though the building was realized, the concept of what would take place in this non-building was not. Originally, the plan was that visitors were prompted to answer a questionnaire before entering the building. The questionnaire generated information about the visitor's personality, which was stored in a raincoat (braincoat) that each user would wear while inside the building. A central network would track the position of each braincoat and compare their profile with other users'. When two users approached each other, the braincoats would compare their users' profiles and indicate the degree of attraction or repulsion of their users. This would be made explicit by colour light and sounds. Green would indicate affinity and red antipathy. There could be up to 400 visitors at the same time. The concept was however not realized due to budget problems.

DUNE X

In 2012 Studio Roosegaarde presented the latest version of their artificial cornfield landscape at the 18th Art Biennale of Sydney. DUNE X was a public art installtion located in the dark 'Dogleg tunnel' and interacted with passing visitors. Having evolving through several contexts and iterations, DUNE X is capable of creating a complex spatial play of lights and sounds reminiscent of grasshoppers. This 'hybrid' of nature and technology is composed of large amounts of fibers that brighten according to the sounds and motion of passing visitors, creating a futuristic and constantly changing space.

The installation consisted of a modular system with each module measuring 100 centimers in length and 50 centimeters in width. The modules held dozens of LED-equipped fibers of variable heights, as well as the system's sensors, speakers and interactive electronics and software. Taking all available modules, the total length of the installation was up to 400 meters.

4.3 Results of the reference study

Using the formulated ingredients for designing with pervasive computing, both projects were analyzed in order to better understand how they function as interactive spaces. This analysis is shown in figures 4.3 to 4.6 on page 52 and 53. On the top of each page is the scheme of pervasive computing components (figure 2.2) repeated and filled out for the two reference projects. Below these schemes is, with help of the 'smart' affordances scheme (figure 3.2), the workings of the interaction on a user-environment level studied.

fig 4.1 Reference project Braincoat, Diller Scofidio + Renfro with studio EAR

fig 4.2 Reference project Dune X, Studio Roosegaarde

Interaction	
Purpose	Communication of visitors' personality compatability
Elements	The visitors, 'braincoats', platform, and fog
Relationships	The platform and fog create the conditions in which the visitor requires the use of the 'braincoat'
Context of use	
Site	A dedicated platform, creating a space in which sight is hindered by a dense fog
Situation	An exposition pavilion that is being explored on foot by exposition visitors
Interface	
Physical interface	Wearable 'braincoats', visitors' relative position and direction of gaze
Procedural embedding	Interaction is embedded into the explorative strolling of visitors
Social embedding	Green or red light, and high- or low-pitched sounds are associated with postive or negative
Technological system	
Perceptive system	Tracking visitors' location and direction of gaze; logging visitors' questionnaires (personality)
Interpretive system	Determining visitor's position and gaze relative to each other; compatibility of personalities
Reactive system	Emitting red or green lights and specific sound patterns in the 'braincoat'

fig 4.3 Decomposition of reference project 'Braincoat'

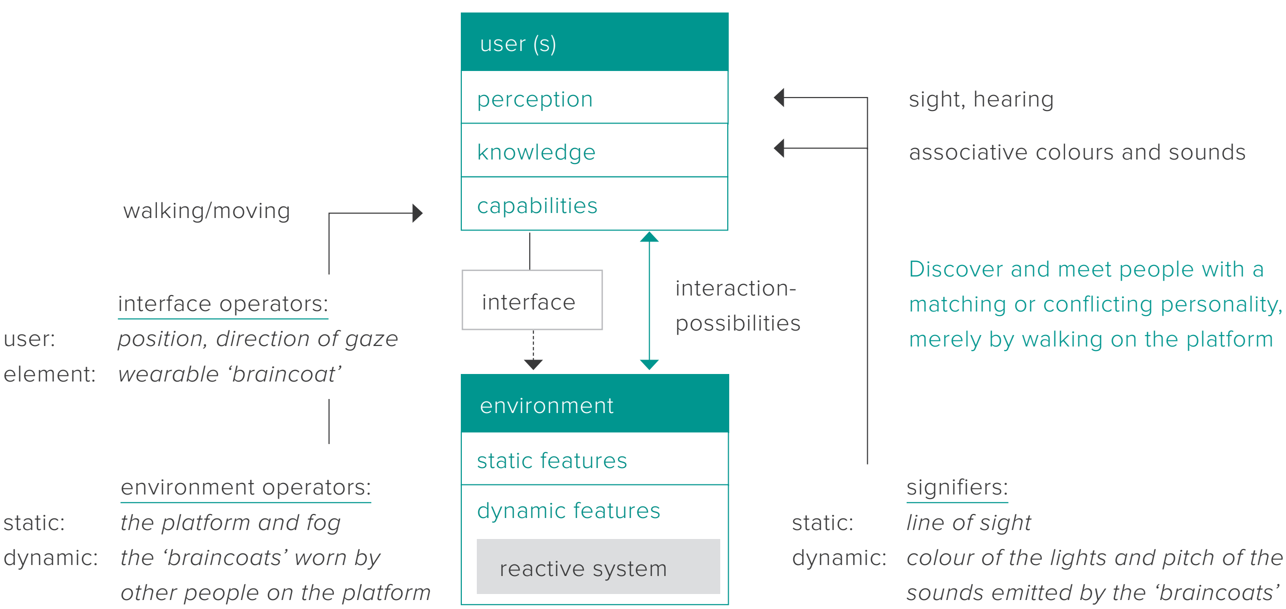


fig 4.4 Analysis of reference project 'Braincoat'

Interaction	
Purpose	A heightened sensory experience
Elements	The passers-by, the light and sound emitting fibers and modules
Relationships	The installations interacts through sound and light with (the movement and sound of) passers-by
Context of use	
Site	A level and open space, defined by the installation itself
Situation	An art-installation that is either visited purposefully or passed through more or less accidently
Interface	
Physical interface	The sound made by passers-by, and their movement through space
Procedural embedding	Interaction is part self-containing activity, and part embedded in the act of walking and talking
Social embedding	The immediate responses of the installlation to the passers-by make the interaction-possibility self-evident. The lights and sounds itself it are not intended to communicate information.
Technological system	
Perceptive system	Tracking the movement of and sounds made by passers-by
Interpretive system	Determining the response in both light and sound, and its spatial distribution over the installation
Reactive system	Emitting spatially distributed patterns of lights and sounds from fibers/modules

fig 4.5 Decomposition of reference project 'DUNE X'

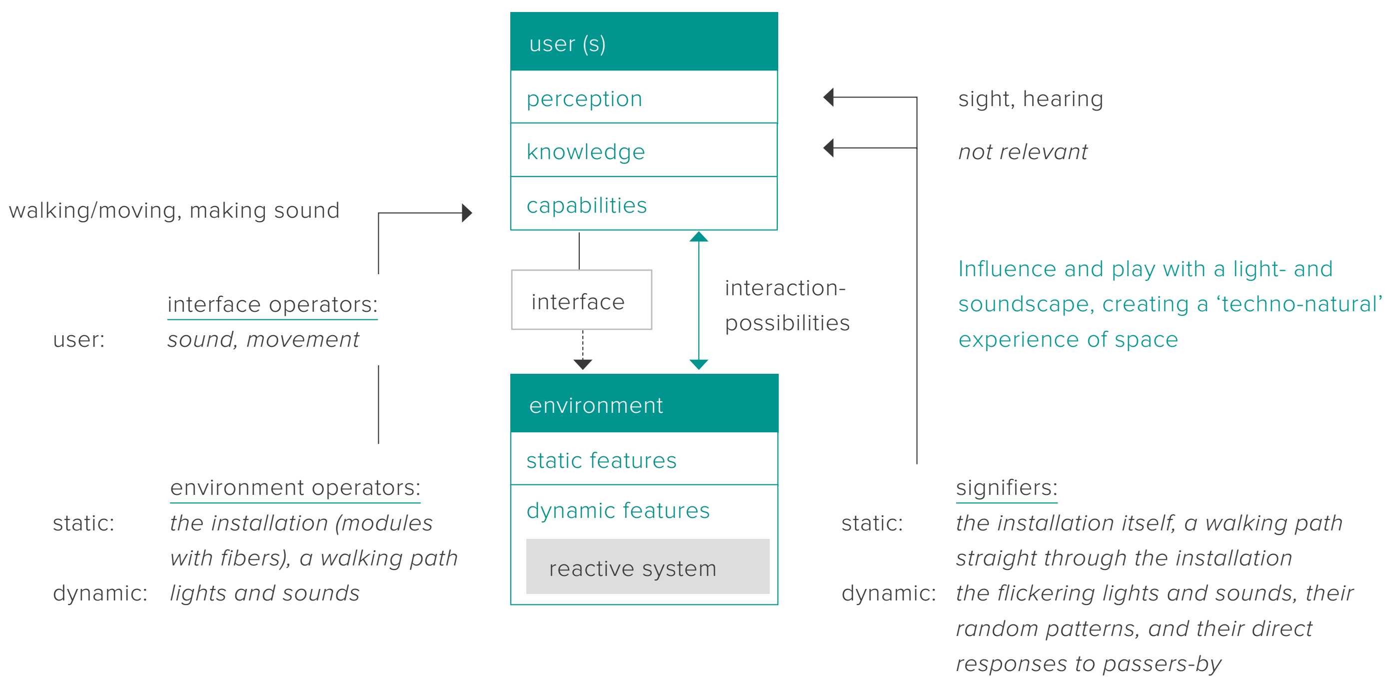


fig 4.6 Analysis of reference project 'DUNE X'

The three other reference projects (see appendix II) not discussed here, as well as for the four other projects that did not comply with the definition, were studied in the same matter. Through comparison of the five schemes with each other and with the non-complying projects, a number of conclusion could be drawn:

Interaction

- Functionality is not the driving force behind the interaction in these projects. A richer experience seems to have the priority. Braincoat, which can be considered one of the more functional examples thanks to its "match-making" capability, is still very much experience-oriented with its focus on atmosphere.

Context of use

- Though it is possible to create a new site for an interaction, it seems more difficult to design a new situation. Braincoat and ADA are examples of this, both developed as new spaces. The situation in which they operated was however pre-determined, being to function as showpiece that is explored and then discarded by users. This could also be a matter of delineating the context of use differently, where the situation extends beyond the site in which the application is actually operational.
- An everyday situation can be turned into a wholly different experience by adding upon it, as project Ampel Pong shows. This project transforms the situation of waiting and hurrying at a crossover into a situation of play through interactive projections.
- The situation has an important role in defining part how the interface can be embedded physically and procedurally.
- An existing action in the situation gains new functionality or meaning through the application (Ampel Pong), or is amplified in functionality or meaning (Sonic City).

Interface

- In all proper reference projects, the user provides input for the perceptive system through ordinary body movements.
- Associative design (social embedding) is used for effective system-user communication.

Technological system

- In all proper reference projects, the reactive system is embedded physically into wearable items or physical or ambient space.

4.4 Conclusion: design lessons

The results from the reference study help understand the design of interactions. Using writings (Chong 2011, Kuang 2013) and a lecture (Roosegaarde 2013) of two experts on the topic of interactive environments, being Studio Roosegaarde (NL) and studio Local Projects (USA), these conclusions can be merged into design lessons that aid in the design of interactive environment. These lessons are listed on the opposite page.

Interaction

1 User-focused, fleeting interactions create a courtship between man and machine (Chong 2011, Roosegaarde 2013).
 > Create *interaction-possibilities* in which the user takes up a key role.

2 Lightweight interactions are fun interactions, complexity kills (Kuang 2013).
 > Use only few *operators* and *signifiers* and, if deemed necessary, create an understandable *relationship* between what the user does (the interface) and how the environment responds (the system output).

Interface

3 Contextual design makes the interface disappear (Chong 2011, Kuang 2013).
 > Use or design *interface operators* that are or can be embedded *physically* and *procedurally* in the *context of use*.

4 Bodily movement makes the interaction work as a natural extension of the user (Chong 2011, Kuang 2013).
 > Use body movement as the predominant *interface operator*.

5 Associative design helps create an intuitive interface (Chong 2011, Roosegaarde 2013).
 > Design *interface operators* and *signifiers* in relationship to each other enabling the user to quickly relate interface with the system's output.

Technological system

6 Overlapping software patterns and their variable influence on each other creates a dynamic system (Chong 2011).
 > Create relationships between the algorithm's *software patterns* with the help of dynamic *input criteria*.

7 Software is a means of granting an otherwise inanimate machine a personality (Chong 2011, Roosegaarde 2013).
 > Design a 'behaviour', or irregularities into the *interpretive system*.

8 The open-ended nature of software allows for organic growth (Chong 2011).
 > Consider the final design not to be an end product but a intermediate product that may need adjustments or fine-tuning when executed in the real world.

9 Sensuous qualities transform imperceptible data into an experience (Chong 2011, Roosegaarde 2013)
 > Use the *dynamic physical and ambient features* of the interactive environment to make otherwise non-explicit information or thoughts perceptible to the user.

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PART II

Landscape Experience

5 Current Theory on Landscape Experience

The previous chapters explained the design of interactive environments. As stated in the introduction of this thesis, this research is focused on utilizing pervasive computing for the design of an interactive type of landscape experiences. In order to merge the design of interactive environments with the design of landscape experience we need to comprehend how we can design for landscape experiences.

For this we direct our attention to the research field of embodied cognition. First, a literature review of Jacobs' (2006) theory on landscape experience reveals what can be designed of these experiences. The theory of conceptual metaphor by Lakoff & Johnson (1980) is then introduced to help explain the design for landscape experiences as the design of physical and ambient landscape features. Finally, the chapter is concluded with the construction of a basic design method for landscape experiences.

5.1 Basics of landscape experience

In his dissertation on a comprehensive theory of landscape experience Jacobs writes the following (2006: 3):

> *"Every neurologically normal person knows what landscape experience is. Simply look out of the window, attend to what you see, and there you have it: an experience of landscape."*

This simple explanation describes landscape experience as a process of embodied cognition, being to perceive the outdoor physical world with our bodily sense of sight, and attend with our mind to information gathered through this sense. Jacobs provides here an example based on gazing from *outside* the landscape upon landscape, while there is also a full *embodied experience of landscape*, in which you are positioned *in* the landscape. Since this research is focused upon situated interactions between people and computer-mediated space as opposed to interactions taking place from behind a desk, we will concern ourselves only with this last type of experience.

Jacobs goes on to explain that landscape experiences are both personal and variable. First, as illustrated in figure 2.1 on the following page, experiences are constructs of the brain derived from an interplay between sensations of the world and states and processes of the own body. Because the involvement of body and brain, experiences of the same landscape differ from person to person. Second, experiences come in a mood, meaning that if you are in a positive mood the experience you have of a landscape will differ from your experience of the same landscape when you are in a negative mood. Hence experiences are variable, differing from mood to mood.

Understanding that experiences are personal and variable, we delve a bit deeper in the process through which they are constructed in order to understand what there is left for designing for experiences. This process is a rather complicated one involving many different factors. Jacobs (2006: 215) provides a conceptual model for this purpose in which he details all the different factors. Because not all of them are of importance to this research, this model is greatly simplified to include only the components considered relevant.

The result of this simplification is illustrated in figure 5.1. In this figure it is immediately obvious that the two inputs for experience coming from outside of the body are the *matterscape*, being the physical and ambient landscape, and the *public expressions,* being the behaviours or products of behaviours expressing thoughts or experiences. Together they form the pool of *stimuli*,

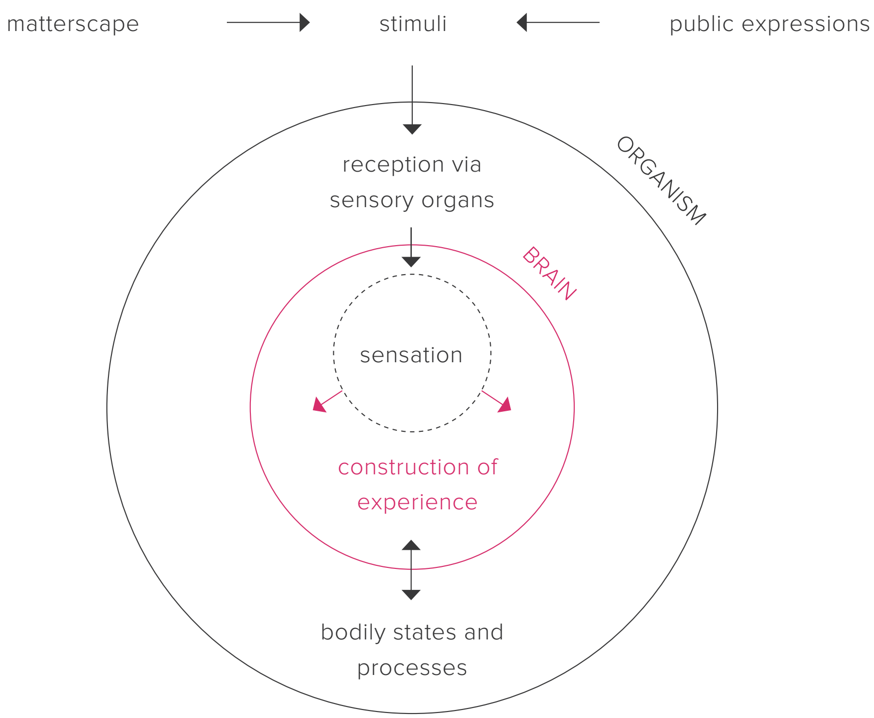


fig 5.1 A simplified conceptual model of landscape experience. Adapted from Jacobs (2006: 215)

picked up and processed by the subject's sense organs. The perceived stimuli are then translated in the brain into visual, tactile, auditory, olfactory and/or gustatory *sensations*. Finally, these sensations together with the states and processes of the subject's body form the input for a complex neurological process in which the actual experience is constructed.

Design relevance

Though the conceptual model for landscape experience makes evident that it is not possible to *design* experiences, it does hint at a certain possibility to *design for* experiences. The physical and ambient environment, referred to as 'matterscape' by Jacobs, provides a large share of the pool of stimuli and as such plays a key role in the construction of landscape experience. Put differently, to design for experience means to design specific *stimuli* (Motloch 2001: 112-121) to which people's senses should attend in order to have specific sensations in the brain. In this thesis we will from here on refer to the design for landscape experience as the *design of sensations*. As opposed to the term 'stimuli', the term 'sensations' refer directly to the visual, tactile, auditory, olfactory and gustatory senses that the designer is targeting. Designing sensations makes for a very precise and easy to communicate design goal.

The designer should understand that though the aim of a design might be to evoke a specific experience, the actual experience as constructed in the brain of the subject is always personal and can therefore differ dramatically from the aim. Hence, its is arguably more effective to design for visual, tactile, auditory, olfactory and/or gustatory sensations which, though they may not be attentively be perceived by everyone, are universal.

5.2 Concepts of experiences

Having discussed the theory of landscape experience, the question arises how a designer can describe an experience in order to be able to link an this experience with actual sensations. Lawrence & Margolis (1999) and Jacobs (2006: 162) help explain that the mental understanding of experiences happens in the brain through *linguistic concepts*; mental constructs that translate experience into language. Typical landscape architectural examples of such concepts are *solitude*, *vibrancy*, and *freedom*. Concepts of experience are abstract in character due to the multitude of sensations from which they are constructed. They can not be used one-on-one to describe physical or ambient features of the landscape. For this an extra step is necessary: the conceptual metaphor.

Design relevance

Concepts of experience can be regarded as vessels for communicating universally understood experiences –they provide the words to capture and describe human states of being. Verbalizing these is extremely helpful for not just the communication of a design, but for the design process itself as well. Defining a desired landscape experience sets a design criteria that, if excecuted well, makes a better and more credible design.

5.3 Conceptual metaphor

Now we understand how landscape experiences are constructed and how we can define and communicate an experience using language, the question arises how we can translate this *concept*, being something abstract, into concrete and universal sensations of the physical and ambient environment. This step (figure 5.2) is facilitated by the theory of conceptual metaphor by Lakoff and Johnson (1980). A *conceptual metaphor* refers to the understanding of one idea, or conceptual domain, in terms of another (referred to as conceptual mapping by Lakoff & Johnson). An example of this is the phrase '*life is a journey*', in which the concept of *life* is described with the metaphor *journey*. Metaphors can be abstract such as in this example, or refer directly to a physical or ambient feature of the environment. An example hereof is to describe the concept

fig 5.2 The conceptual metaphor as an intermediate step between the linguistic concept of an experience and the actual sensation in the human brain.

fig 5.3 An example of an abstract concept described in physical and ambient sensations through conceptual metaphors.

important with the metaphor *big*, used in phrases such as '*this is big news*'. As shown in figure 5.3, this concept can be described with a variety of metaphors relating to physical sensations (concerning form and substance), or ambient sensations (concerning all sensory appearance).

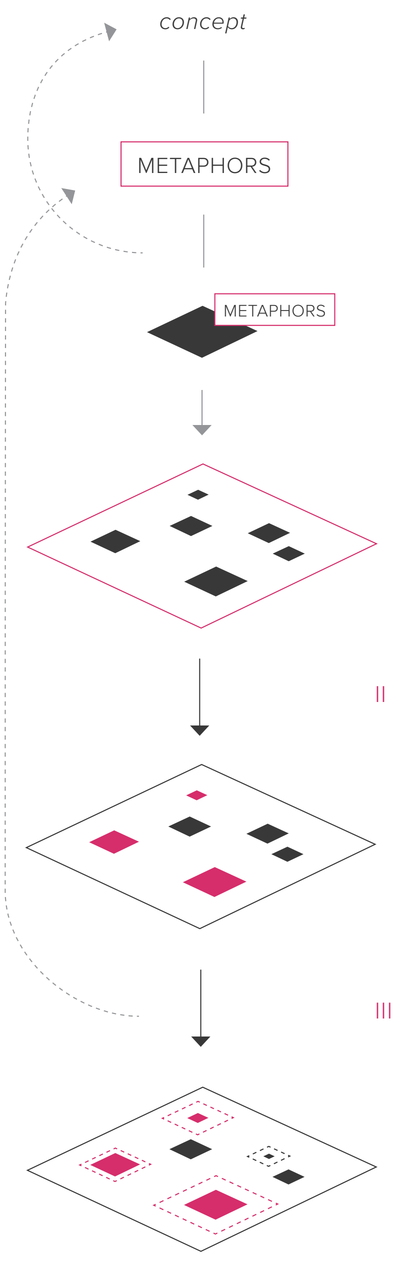
Design relevance

As is apparant, conceptual metaphors are of great use to a variety of designers (Hendrix 2013), including landscape architects. They are a crucial tool to transform abstract concepts of experience into concrete sensations of the physical and ambient environment. What designers may already do by intuition can be done in a significantly more structured and thorough manner with the help of conceptual metaphors.

5.4 Conclusion: designing sensations

Through a literature review of Jacobs' theory on landscape experience we have have gained an understanding of how landscape experiences are constructed and learned that landscape architects can employ *sensations* in the design for landscape experiences. Lakoff & Johnson's theory of conceptual metaphor helped further explain the design for landscape experience by providing an intermediate step between the abstract concepts of landscape experience and the design of sensations.

We can conclude this chapter with a basic design method for landscape experience, shown on the opposite page. This method takes the desired landscape experience of a location as point of departure and guides the designer in six steps towards concrete design interventions. These interventions lead to a design that aims to deliver 'amplified' sensations, which through their metaphoric references relate to the desired experience. Even though this specific experience may not be constructed in the brain of all beholders, the sensations and their metaphoric references as targeted by the designer can be –thanks to their universal value– recognized by all.



I Analysis

1 Describe the desired landscape experience of the design location (site) through one linguistic concept.

2 Map the conceptual metaphors that explain this concept in physical and ambient sensations.

3 Link the collected metaphors to the existing physical and ambient features of the site. If there seems to be incongruency between the collected metaphors and the site, redefine the concept of experience.

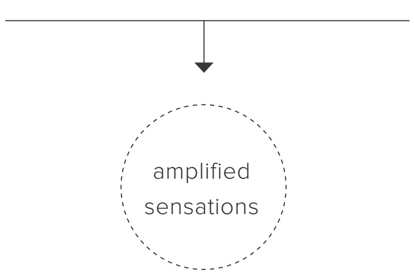
4 Define the boundary of the 'scene' by locating and assessing the relevant edges of these physical and ambient features.

II Possibilities

5 Select the key features of the scene. These are the most prominent, readily perceivable stimuli that most strongly represent the desired experience through their metaphoric reference.

III Design

6 Formulate specific design interventions to improve the perceivability and effectivity of the key features and their metaphoric reference. Also consider design interventions for non-key features and features within the site boundary that may conflict with or disturb in achieving the desired experience. If there seems to be incongruency between perceived design opportunities and the assigned metaphors, consider remapping the conceptual metaphors.



Result: the design delivers amplified sensations that, through their metaphoric references, relate to the desired landscape experience.

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PART III

A Design Method

6 Constructing a Design Method

Having investigated the design of interactive environments and the design for landscape experience, we can perform a comparative analysis to define overlaps and similarities. Through this analysis it becomes possible to merge the two seperate objects of study into a cohesive design method for interactive landscape experiences.

The chapter starts with a brief overview of the previous research findings. We then move quickly move to the comparison and conclude with the formulation of a design method.

6.1 An overview

The research shown in the previous chapters resulted in an understand of how interactive environments could be constructed and how landscape architects can design for landscape experiences. Over the course of these chapters one may already have catched glimpses of where both topics connect. Some are quite obvious and others less so. Before we move in to the identification of all these points in the comparative analysis, this paragraph will first provide an overview of the research result so far.

These results are the product of a constant check between the theory and its relevance to design, be it the design of interactive environments or design for landscape experience. Some of the discussed concepts were relevant to design in its most broadest sense while others were specifically relevant to the design of space, as it is conceived in landscape architecture.

Design of interactive environments

The design of interactive environments is about the design of interface operators, environment operators and signifiers that together create interaction-possibilities. In the design process one has to:

1. Analyse the *context of use*, which delineates possible purposes of the interaction. Consists of decomposing the *site*, the physical and ambient features, and *situation*, the actions and circumstances in which people are engaged.
2. Define the *interaction*. Consists of formulating its *purpose*, selecting the interaction *elements* from the context of use and creating interaction *relationships* between these elements and people.
3. Design the *interface*. Consists of designing the *physical interface* (the interface operators) and embedding this *procedurally* and *socially* in the context of use.
4. Design the *technological system*. Consists of formulating: the *external*, *ambient* and *interface inputs* (the perceptive system); the *dynamic input criteria* and *software patterns* (the interpretive system); and the *physical* and *ambient output* (the reactive system), which lead to the design of the environment operators and signifiers.

Design for landscape experience

The design for landscape experience is defined in this thesis as the design of *sensations*. Taking a desired landscape experience as point of departure –

either one of the design context to 'enhance' or to 'newly introduce'– we define this experience with a *linguistic concept*. With the help of conceptual *metaphors* this linguistic concept can be translated into generic physical or ambient qualities. These can then be mapped onto actual *features* of the design location and serve to define the *boundaries of the 'scene'* within which the design should focus. From this scene the landscape architect can select key features and design interventions in these features and/or introduce new ones. As result, these design interventions should lead to *'amplified' sensations*, that through metaphoric reference refer to the desired landscape experience.

6.2 Comparative analysis

The comparative analysis of the design method for interactive environments and the design method for landscape experience shows three points of overlap:

1. The aim or purpose of design

In the literature review of Jacobs' theory on landscape experience we identified the design of *sensations* as a way to design for a desired landscape experience. With the introduction of pervasive computing in the design, these sensations can be made 'dynamic' –meaning that they change over the course of an interaction between people and an environment. In essence, these *dynamic sensations* are the method of communication for the computer-mediated environment: the output of the technological system and the signifier of the interaction. Whereas the design method for interactive environments asked for a purpose of the interaction, the design method for landscape experiences provided one: sensations. The concept of dynamic sensations thus ties the design of interactive environments seamlessly together with the design for landscape experiences.

2. The delineation of the working space

The second point of overlap is the similarity between the *context of use*, from the design method of interactive environments, and the *'scene'*, from the design method for landscape experience. Whereas the scene is a systematically delineated space based upon an analysis of the desired landscape experience, the context of use is more fluid in its definition. Both are nonetheless compatible, as they are in essence about the working space. The combination of the two results in a systematical delineation of the site and situation of the interactive landscape experience.

3. The selection of the key elements of design

In the study on pervasive computing we defined interaction *elements* as the keys in the design of interactive environments. The selection of these elements from the context of use, as well as the introduction of new elements, happens in accordance with the purpose of the interaction. In the design method for landscape experience we suggested to make a selection of physical and ambient key features, based upon their strong metaphoric reference to the desired landscape experience. Both selection processes can be merged effortlessly by taking the key features selected for their metaphoric reference as key elements for the interaction.

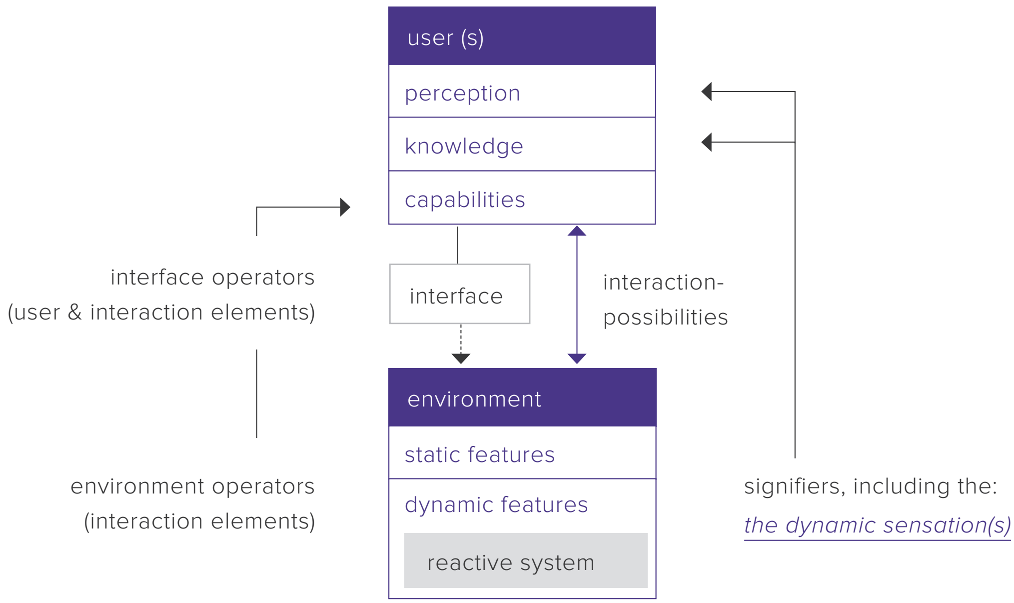


fig 6.1 A 'smart' affordance including the concept of *dynamic sensation* as signifier.

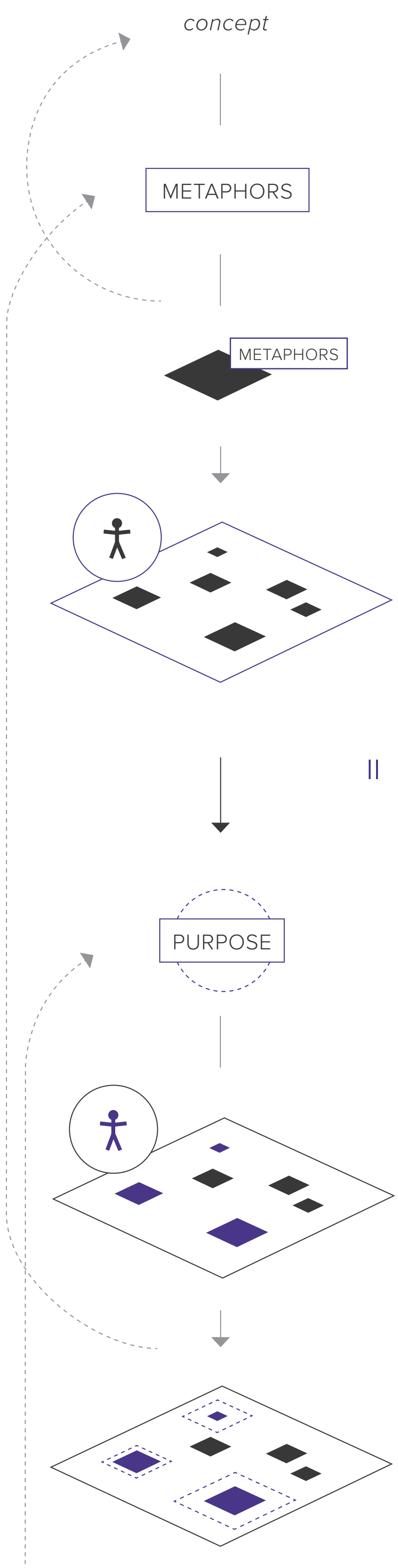
6.3 Constructing the design method

The synthesis made in the previous paragraph made it possible to develop an integral design method aiming for interactive landscape experiences, presented on the following two pages. The method consists of three phases:

1. The *analysis phase*, in which the desired landscape experience is formulated as linguistic concept and deconstructed into conceptual metaphors. The working space (scene, or context of use) is defined by linking these metaphors to physical and ambient features of the landscape.
2. The *possibilities phase*, in which the purpose of the interaction, being the dynamic sensation(s), is determined. Based upon the purpose, possible selections of key features (or, interaction elements) and design interventions are explored and defined.
3. The *design phase*, in which the interaction and the interactive environment are designed. Relationships between the interaction elements are constructed in order to select the element(s) that will create the dynamic sensatio. The sensation is then designed along with the interface and the basics of the technological system (the dynamic input criteria and software patterns).

The eleven steps taken over the course of these three phases lead to the design of a dynamic landscape sensation that faciltates an interactive landscape experience.

I Analysis



1 Describe the desired landscape experience of the design location (site) through one linguistic concept.

2 Map the conceptual metaphors that explain this concept in physical and ambient sensations.

3 Link the collected metaphors to the existing physical and ambient features of the site. If there seems to be incongruency between the collected metaphors and the site, redefine the concept of experience.

4 Define the boundary of the site by locating and assessing the relevant edges of these physical and ambient features; this is the *context of use* (the *site* and *situation*) in which the interaction is to take place.

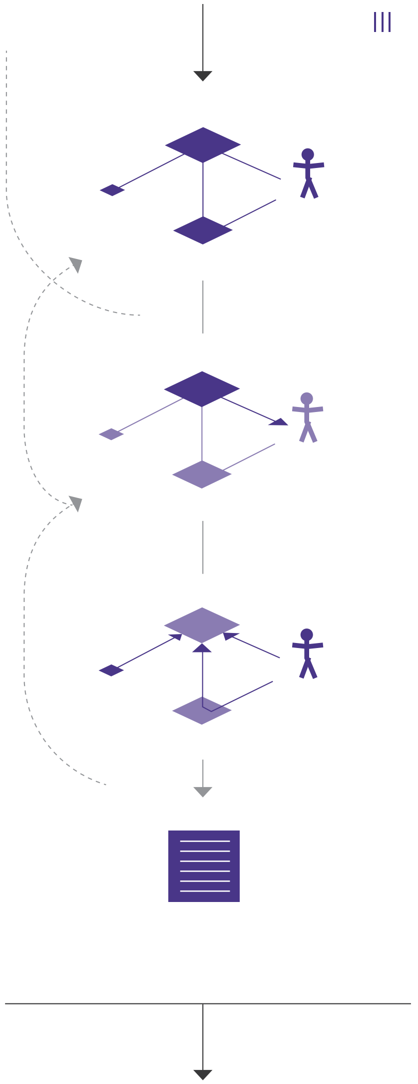
II Possibilities

5 Formulate the *purpose* of the interaction, being a or multiple sensation(s) that metaphorically refer to a landscape experience.

6 Select from the context the key features/stimuli that form the *elements* (users, physical features, and ambient features) of the interaction, and/or define new ones, that are associated with the purpose of the interaction.

7 Formulate specific design interventions to improve the perceivability and effectivity of the key features and their metaphoric reference. Consider also design interventions for non-key features and features within the site boundary that may conflict with or disturb in achieving the desired experience. If there is incongruency between perceived opportunities and the assigned metaphors, remap the conceptual metaphors.

III Design



8 Create *relationships* between these elements, giving the purpose of the interaction and the interaction itself its actual form.

9 Select the element(s) that will represent the dynamic sensation. Formulate its output and design the *environment operators* and the *signifiers*.

10 Formulate the input from the elements (ambient data) and interface, and design the *interface operators*,

11 Formulate the (dynamic) *input criteria* and *software parameters*.

interactive landscape experience
through dynamic
landscape sensations

7 Testing the Design Method

The previous chapter presented the product of this research: a design method for interactive landscape experiences. In order to verify is usefulness and validity the method was used in a prototype design for the island of ‘Tiengemeten’, presented in this chapter.

First the design context is detailed, leading to the formulation of a design concept. From this concept one ‘scene’ is taken to illustrate how the design method was applied. The chapter is concluded with an overview of the design.

7.1 Introduction to Tiengemeten

As introduced in the first chapter of this thesis the island of Tiengemeten was selected as test case for a prototype design of interactive landscape experiences. Tiengemeten, located in South Holland (The Netherlands) in a one-hours drive of the city of Rotterdam is a nature reserve marketed by property holder Natuurmonumenten as a hiking paradise that offers free exploration of tidal nature in its infinite variety (Natuurmonumenten 2013). Taking in a position as designer, I argue that Tiengemeten does however lack attractive and captivating landscape experiences –especially when taking into account the many people whom may have no particular relationship or bond with 'nature'. The design challenge is to create appealing and immersive interactive landscape experience.

7.1.1 Site analysis

The analysis of Tiengemeten led to two important observations:

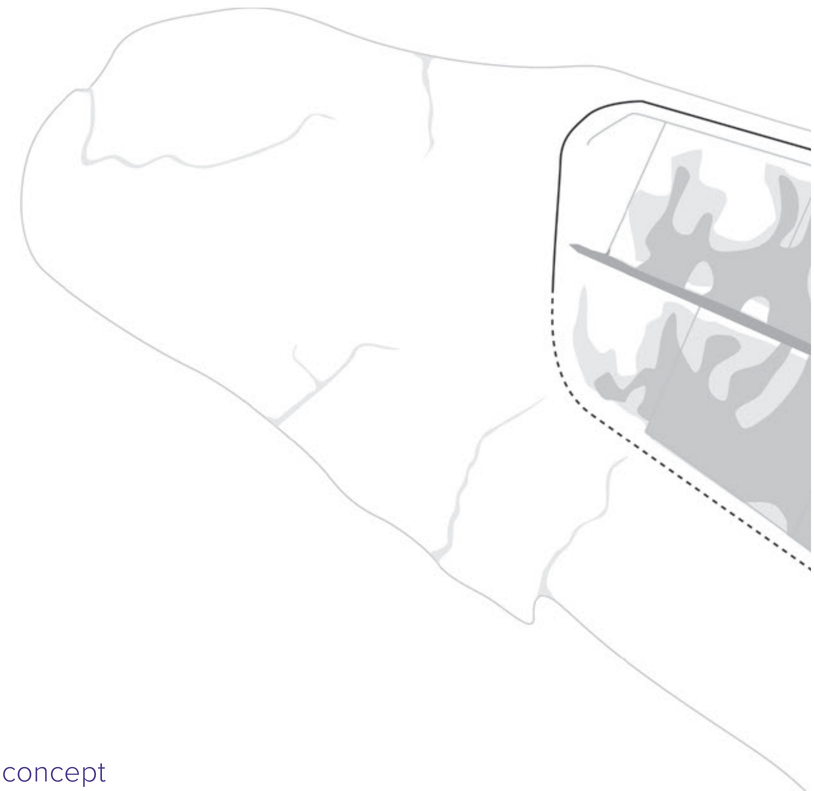
1. Discrepancy between the desired ecology and the reality.
   Tiengemeten, formerly an intensive agricultural landscape, underwent a dramatic transformation in order to create a rare fresh water tidal ecology. A number of interventions, such as the lowering of dykes and digging of creeks, should have led to the creation of this ecology. The reality turned out differently; the current tidal difference in the Haringvliet is insufficient to facilitate a tidal ecology (Bruin, C. de & Zanden, K. van der 2011).

2. Available routing does not maximize the available potential.
   The island has three recreational routes along parts of the island, varying from three up to ten kilometres in length. None of these routings cover all of the island's highlights. In addition, they run along the edges of the island and nature areas ('Weelde', a large seasonal marsh that fills up in autumn/winter and dries up partly during spring/summer, and 'Wildernis', a tidal marshy pasture) prohibiting a more immersive experience of the nature.

7.1.2 Design challenge

The observations from the site analysis led, in an interplay with the design method, to the formulation of the following design challenge:

To design a single route that (a) covers the important highlights of the island and (b) integrates a solution to the tidal issue, and does this all with a focus on creating dynamic sensations for interactive landscape experiences.

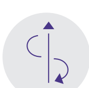


7.2 Design concept

In the design concept, the routing is seen as an anthology of different interactive landscape experiences. The concept is built upon three simple principles:

One comprehensive route that covers all important highlights in the Weelde and Wildernis areas in a timeframe of three hours.

The routing consists of multiple scenes that each aim for a particular landscape experience through dynamic landscape sensations.



The routing is made up of two parts. The first part is a straight cross-section of the island, in which the visitor can take up the size of the island. The second part is ‘the way back’, focused on more subtle landscape experiences.

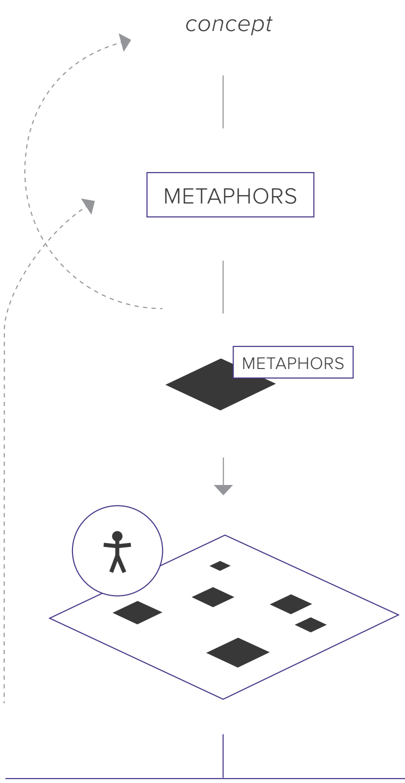
7.3 Applying the design method

Based upon the design concept, a selection of personal experiences was made. These selected experiences, shown in the map below, are the scenes that each will present a different dynamic sensations. These sensations should, through their metaphorical reference, relate to the selected experiences. One of these scenes is used on the following pages to illustrate how the design method can be applied. This is the *'solitude' scene*.

fig 8.1 A map of island Tiengemeten with an outline of the route and chosen scenes

fig 8.2 The 'solitude' scene on Tiengemeten during summer, when the water level is at its lowest.

7.2.1 Analysis



1 Describe the desired landscape experience of the design location (site) through one linguistic concept.

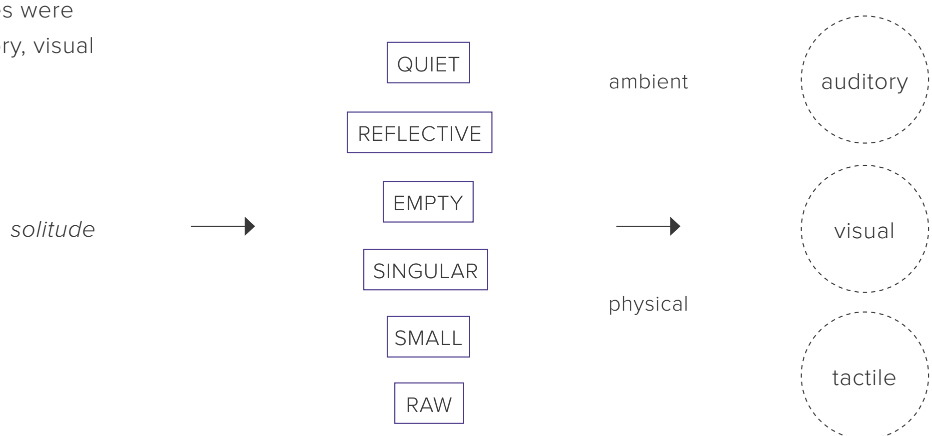
2 Map the conceptual metaphors that explain this concept in physical and ambient sensations.

3 Link the collected metaphors to the existing physical and ambient features of the site. If there seems to be incongruency between the collected metaphors and the site, redefine the concept of experience.

4 Define the boundary of the 'scene' by locating and assessing the relevant edges of these physical and ambient features; this is the *context of use* (the *site* and *situation*) in which the interaction is to take place.

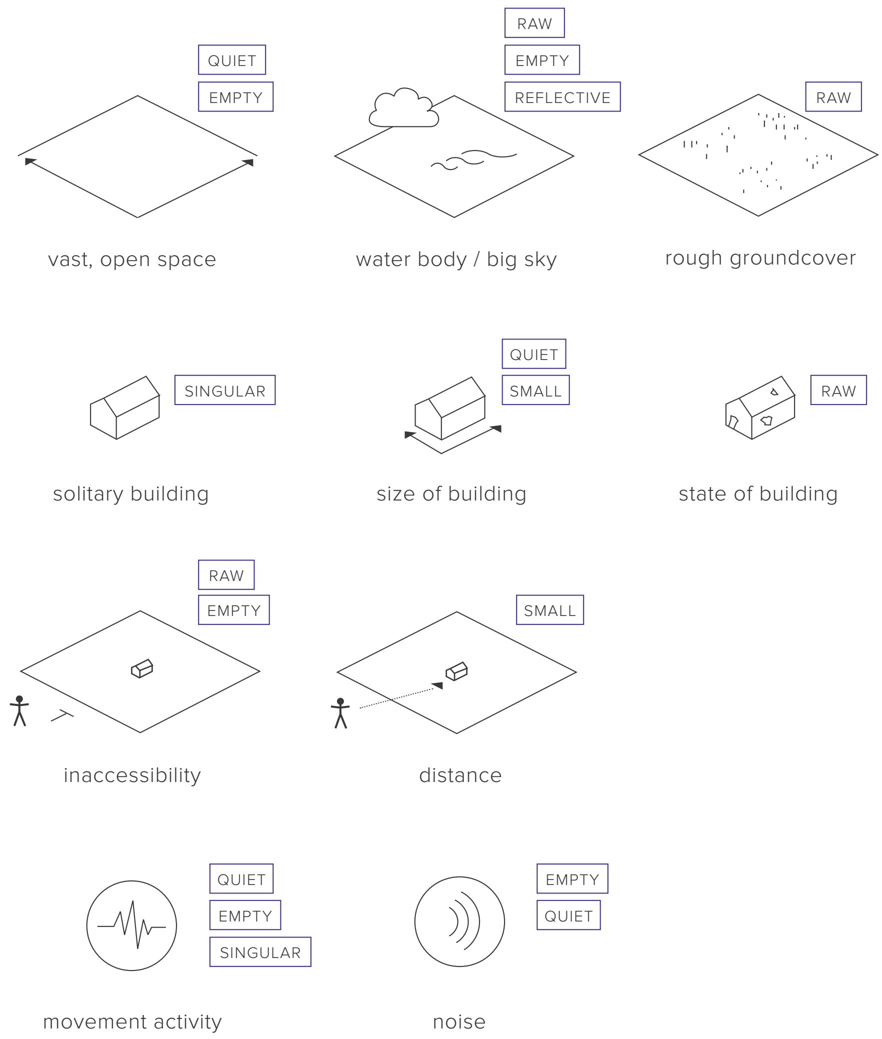
Step 1 & 2: concept and metaphors

The desired experience of this scene was defined by the linguistic concept of *solitude*. With the help of conceptual metaphors a serie of ambient and physical features were formulated. These are auditory, visual and tactile sensations.



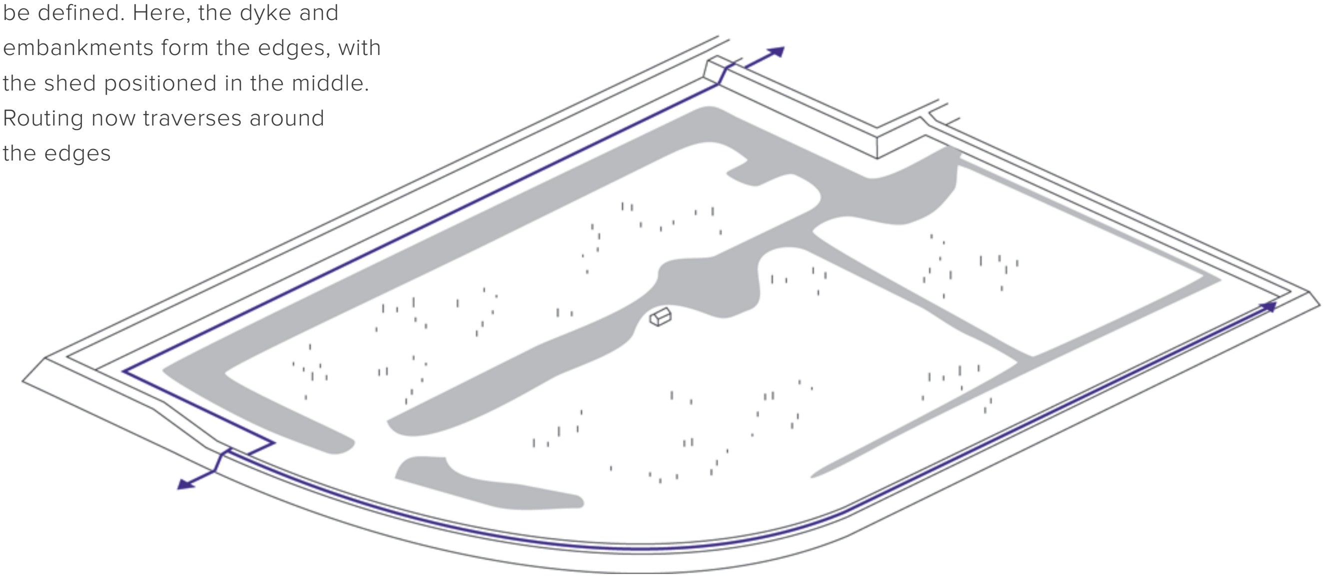
Step 3: features

The collected metaphors are then linked to the actual features of the location. These features can be categorized as space, artifact, related to visitor, and happenings.

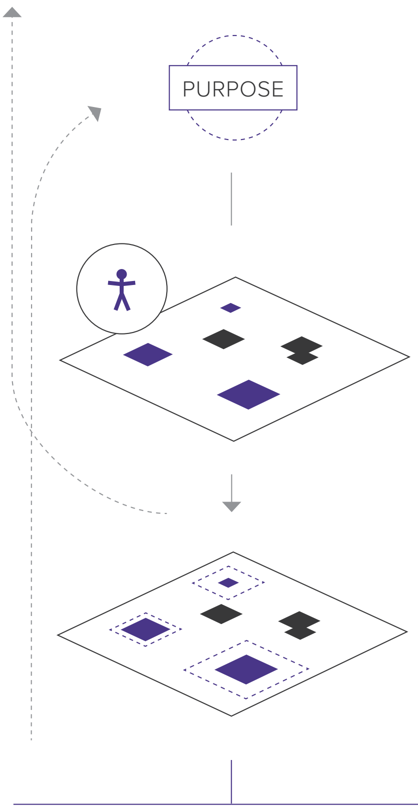


Step 4: scene overview

Having identified the features, the scene and context of use can be defined. Here, the dyke and embankments form the edges, with the shed positioned in the middle. Routing now traverses around the edges



7.2.2 Possibilities



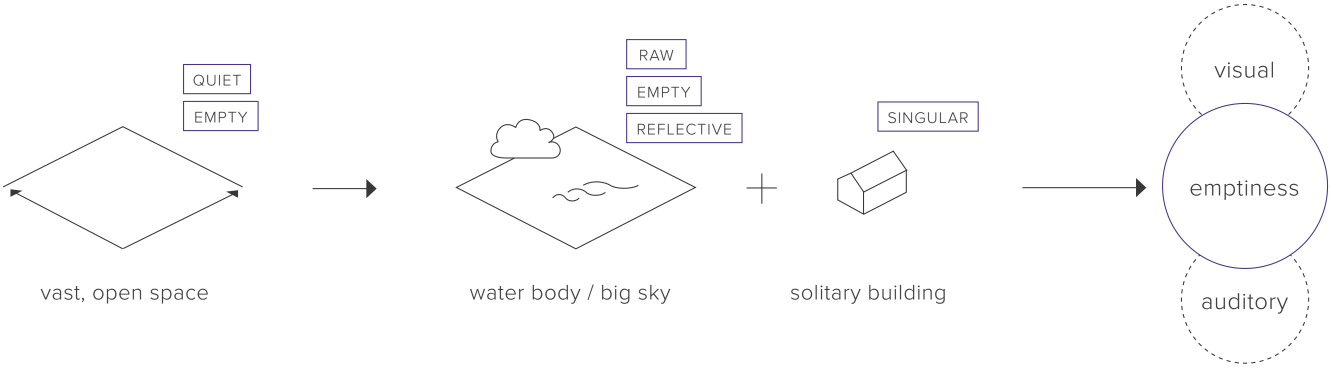
5 Formulate the *purpose* of the interaction, being one or multiple dynamic sensation(s) that metaphorically refer to a landscape experience.

6 Select from the context the key features (physical and ambient) that form the *components* of the interaction, and/or define new ones, that are associated with the purpose of the interaction.

7 Formulate specific design interventions to improve the perceivability and effectivity of the key features and their metaphoric reference. Consider also design interventions for non-key features and features within the site boundary that may conflict with or disturb in achieving the desired experience. If there is incongruency between perceived opportunities and the assigned metaphors, remap the conceptual metaphors.

Step 5: purpose, the dynamic sensation

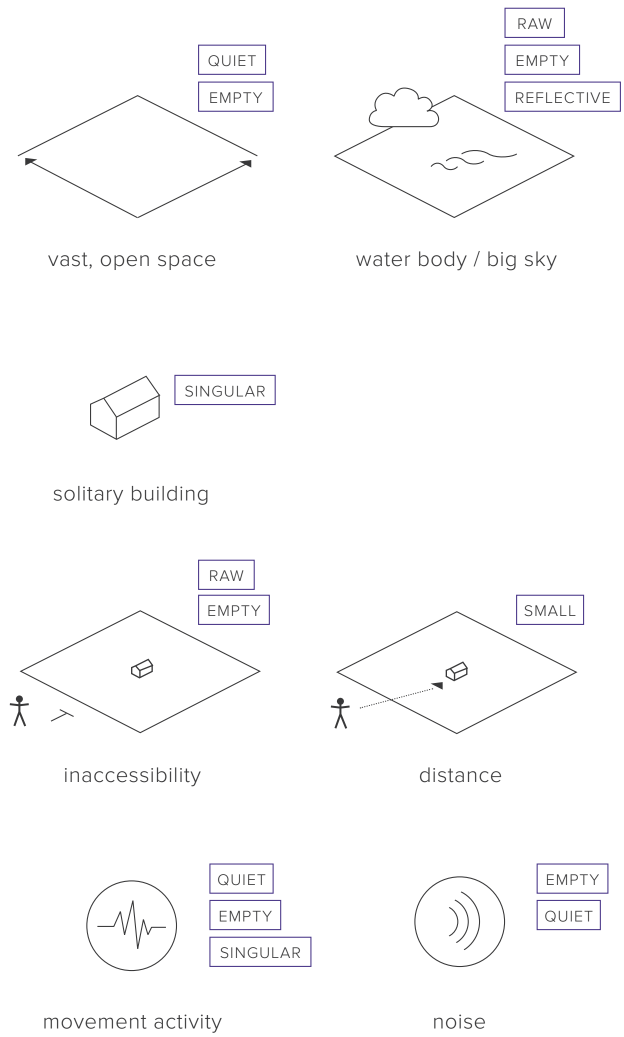
The purpose of the interaction is defined as the dynamic sensation of emptiness, or 'dissappearance'. This can be both a visual and auditory (lack of sound) sensation. This sensation was chosen for two reason. First, the metaphor 'empty' was come across most often in step 3, where metaphors were linked to the actual features of the environment. Second, when studying how this scene is perceived, it is the vast open space that draws attention to the water, and then to the small shed that emphasises the emptiness.



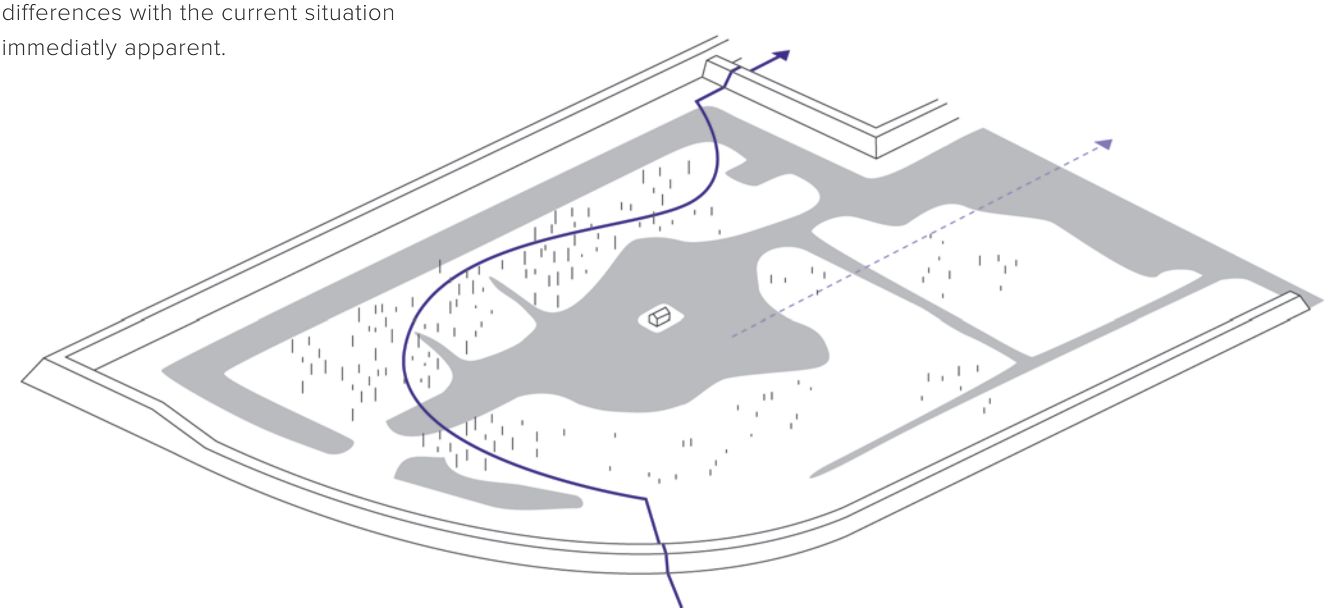
Step 6 & 7: components

From the context the features are selected that (can) play a key role in the sensation of emptiness. Design interventions were formulated to improve the perceivablity and effectivity of these features. These were:

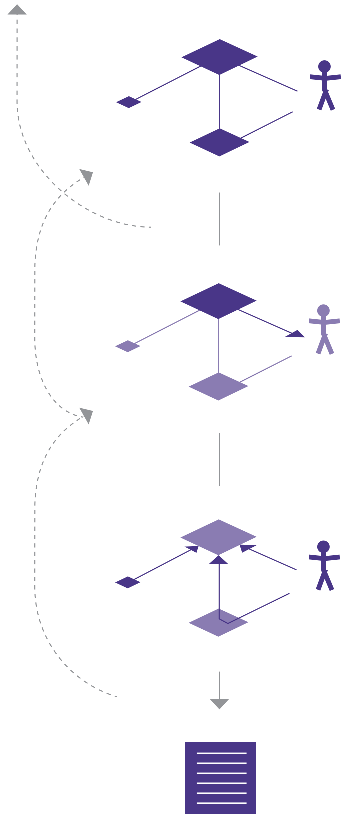
- contrast enclosed spaces with the vast open space
- greaten sensuous contact with the water body
- enlarge the water body
- empasize the solitary position of the building
- greaten overall inaccessibility
- shorten distance on strategic points
- reduce visible movements
- reduce perceptible noises on strategic points



This simple illustrations is a conceptual example that makes the differences with the current situation immediatly apparent.



7.2.3 Design



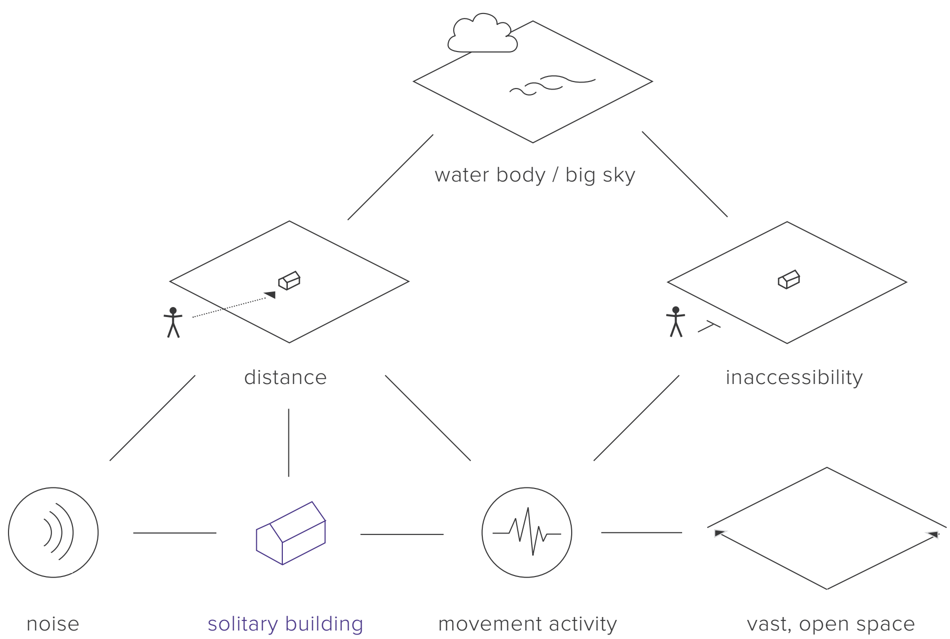
8 Create *relationships* between these elements, giving the purpose of the interaction and the interaction itself its actual form.

9 Select the element(s) that will create or enable the perception of the dynamic sensation. Formulate its output, the dynamic sensation, and design the *environment operators* and the *signifiers*.

10 Formulate the input from the elements (ambient data) and interface, and design the *interface operators*,

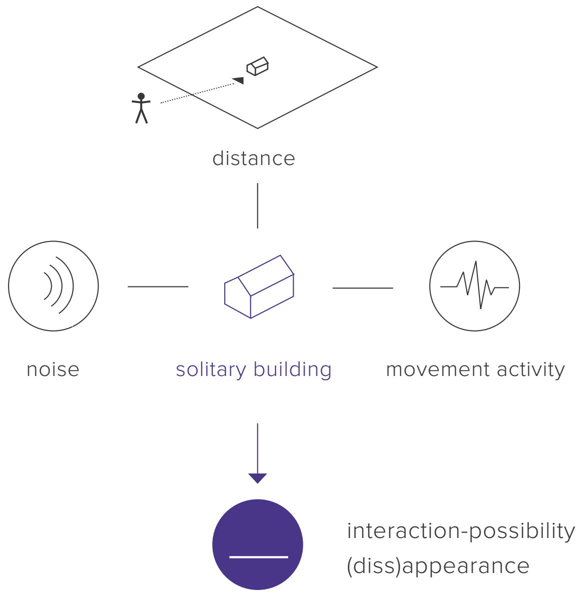
11 Formulate the (dynamic) *input criteria* and *software parameters*.

Step 8: relationships
The relationships between the selected elements are explored by setting them out in a scheme. By doing so, it becomes clear that three elements take up key roles, being the building, the distance of the visitor to this building and the movement activity in the scene.



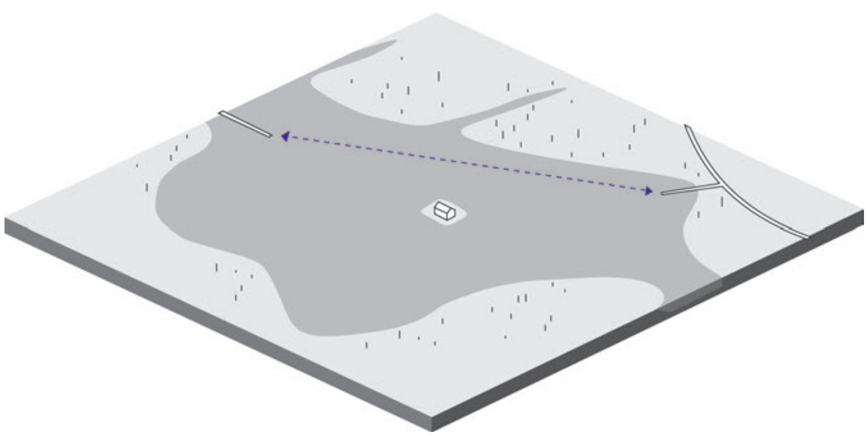
Step 9: interaction-possibility

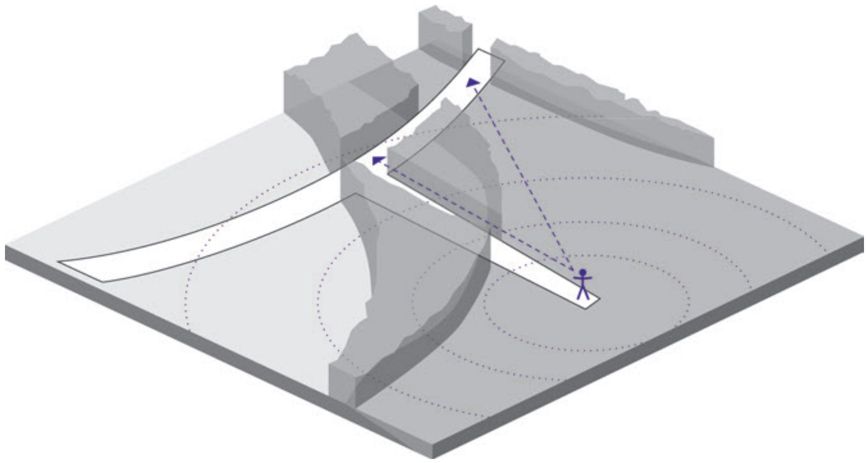
The solitary building appeared to play a key role in the scheme of the previous step. The dynamic sensation will be provided by this building. In response to visitors' distance to the building, the number of visitors nearby and the noise and movements made by visitors, the building will seem to 'dissappear'. This could be achieved through a variety of camouflage techniques.

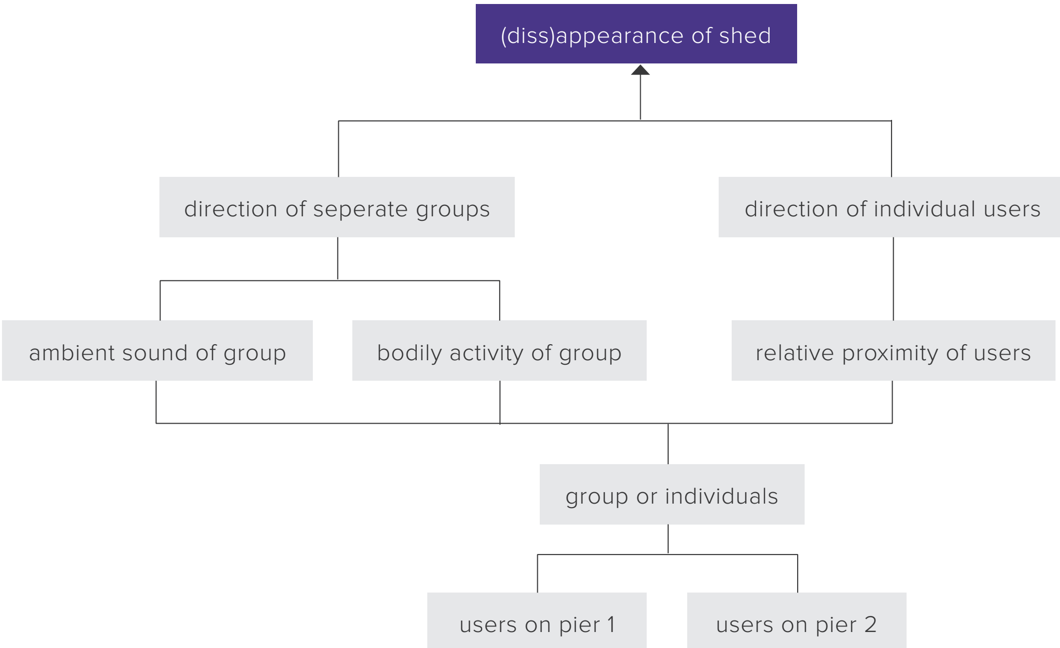


Step 9 & 10: signifiers and operators

Visitors can relate the (diss) appearance of the building to the activities occurring on the other pier (the upper image) as well as to the activities and noises occurring near the visitor itself. It is only when other people are in possible line of sights or within hearing distance and producing quite some noise that the build seems to dissappear.







Interaction	
Purpose	A dynamic landscape sensation of visual *emptiness*
Elements	The visitors, the meandering pathway, the two piers and the shed
Relationships	The shed (diss)appears in response to human actions on one or both piers
Context of use	
Site	A natural, mostly unaccessible landscape with lake, marshes, reed fields and an elevated pathway
Situation	The last part of a walking route through nature, where the visitor walks on an elevated pathway
Interface	
Physical interface	The visitors' absolute and relative position, direction of gaze
Procedural embedding	The interaction is embedded into the explorative stroll along the lake
Social embedding	Not relevant, in this interaction the user should not know how to provide input
Technological system	
Perceptive system	Tracking visitor's location, direction of gaze, registration of human-produced sound levels
Interpretive system	Determing whether visitors' on the pier can see and hear other visitors on the pathway or other pier. Determining relative crowdedness and the individual groups to which the visitors' belong
Reactive system	The visual (diss)appearance of the shed through a camouflage technology

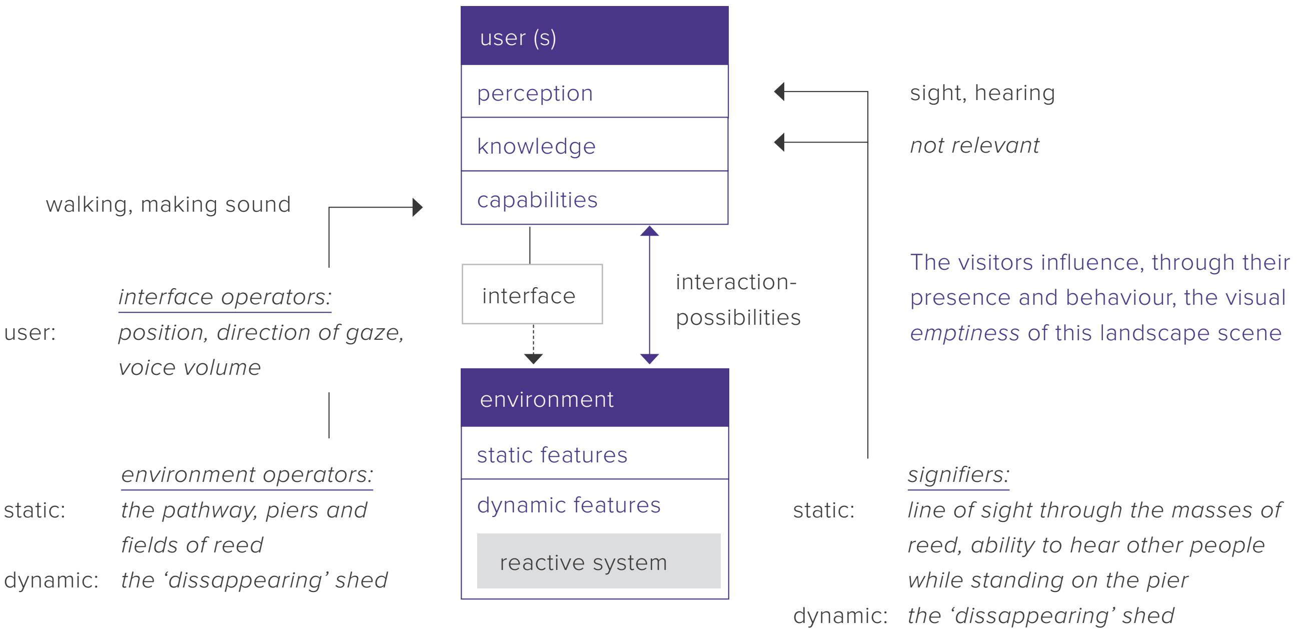


fig 8.3 Deconstruction of the interaction in the same manner as was done for the reference projects.

fig 8.4 Schematic plan of the 'solitude' scene.

Legend

- pathway
- elevated pathway
- unpaved road
- dyke (+4 metres)
- embankment (+2 metres)

- sightlines
- buildings
- refuge hil
- trees
- reed fields

- permanent water
- water level in spring/autumn
- water level in winter

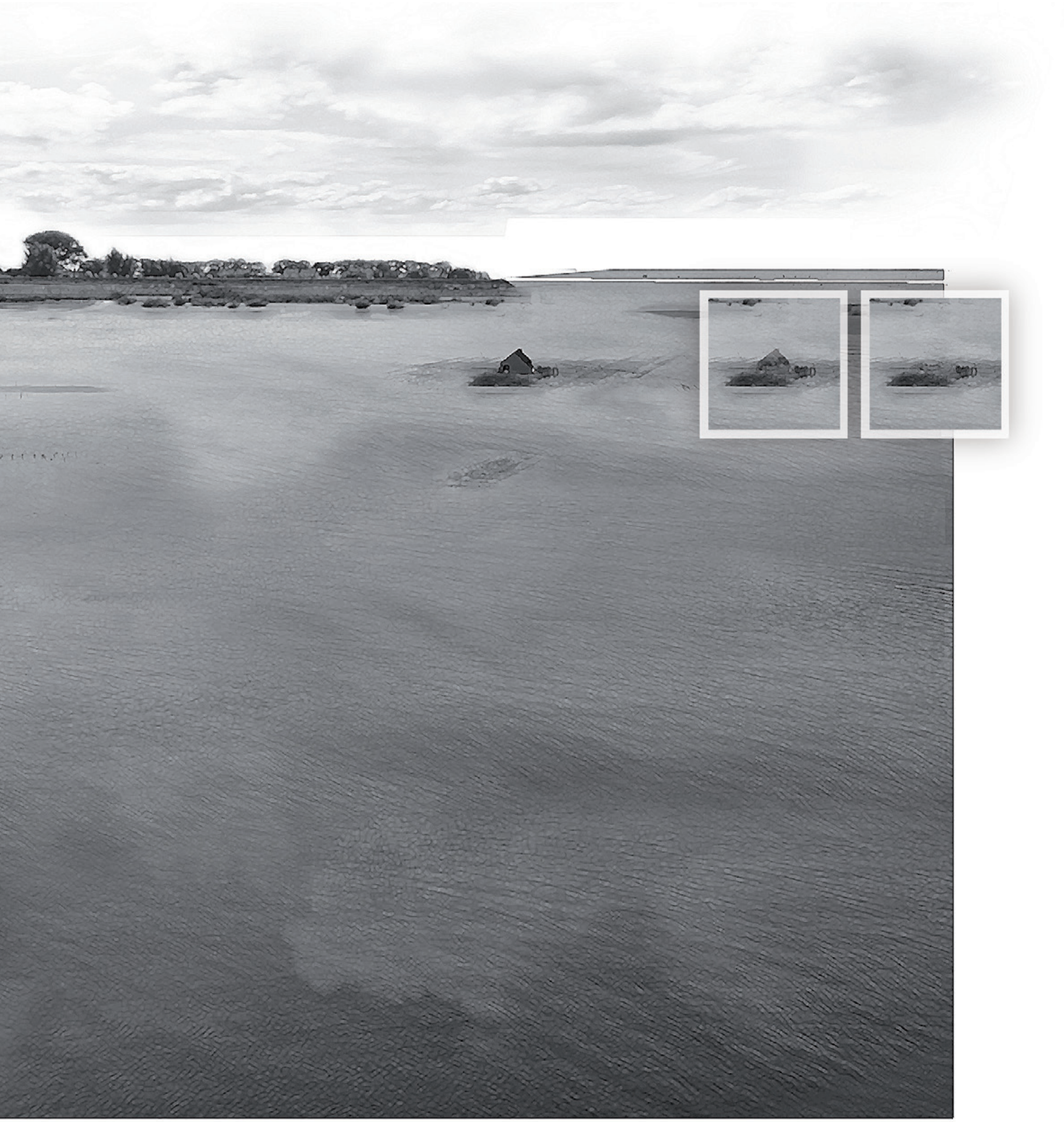
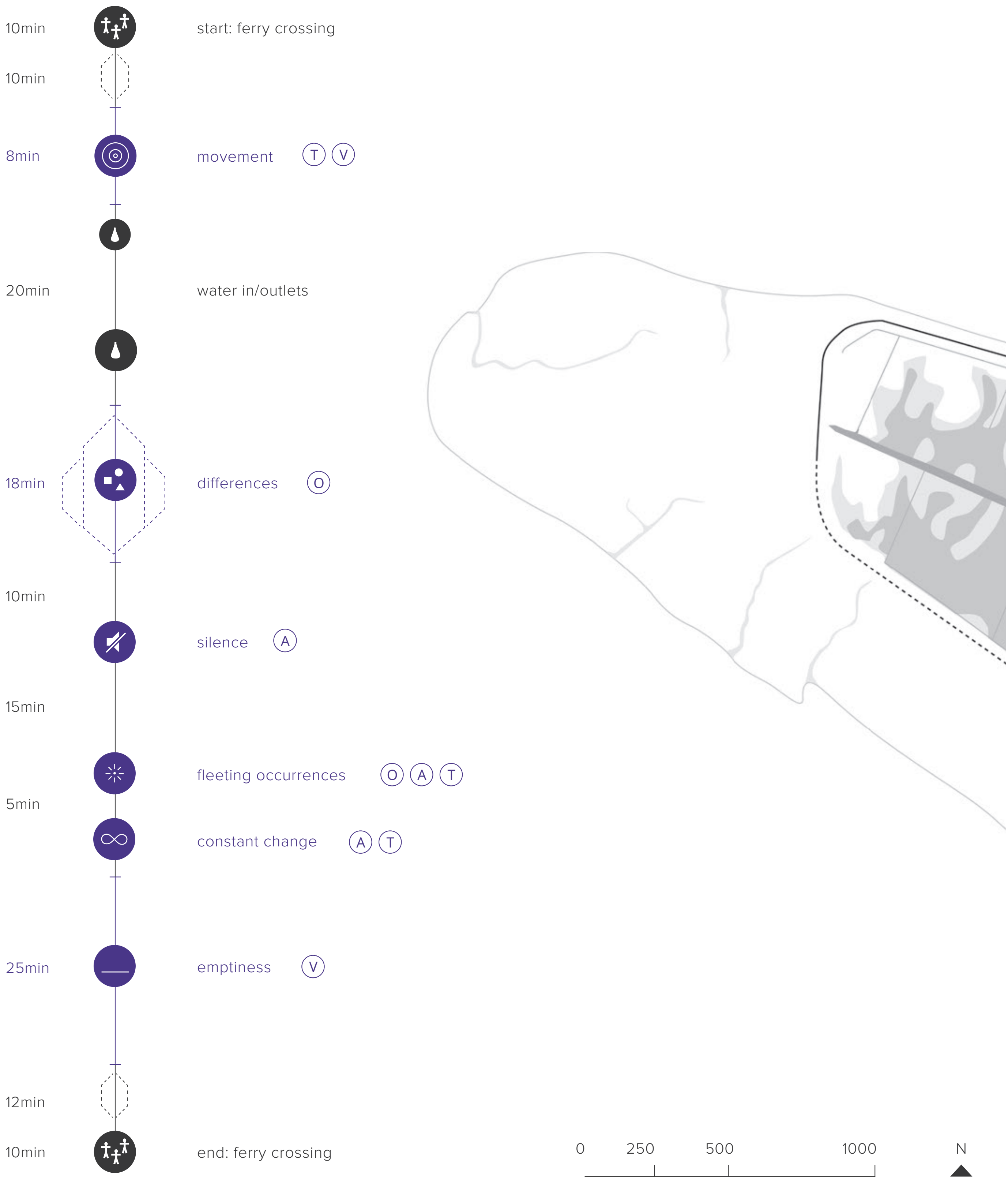


fig 8.5 The ‘solitude’ scene on Tiengemeten as proposed in the design.


10min
start: ferry crossing
10min
8min
movement
T
V
20min
water in/outlets
18min
differences
O
10min
silence
A
15min
fleeting occurrences
O
A
T
5min
constant change
A
T
25min
emptiness
V
12min
10min
end: ferry crossing
0
250
500
1000
N

7.4 Design overview

We have now seen the process through which the various scenes along a new routing were designed. This paragraph takes you along this route by describing the narrative of the complete design.

start: ferry crossing

We start at the small harbour from where the ferry to Tiengemeten departs. The vending machine from which people can buy a ticket does not spit out the usual paper tickets, but instead provides each visitor with an electronic wristbands. These wristbands serve not only as proof of payment for the crossing, but help make the technological system work. Integrated technology provides input on various statistics about the visitor. When the ferry has been boarded and the visitors find themselves grouped together on such a confined space, the wristbands slowly start to glows softly in accordance with the swaying of the boat. This joint and eagerly pulsation creates a sense of community and anticipation of what is coming. When the ferry reaches the shore of Tiengemeten, the wristbands slowly dim again.

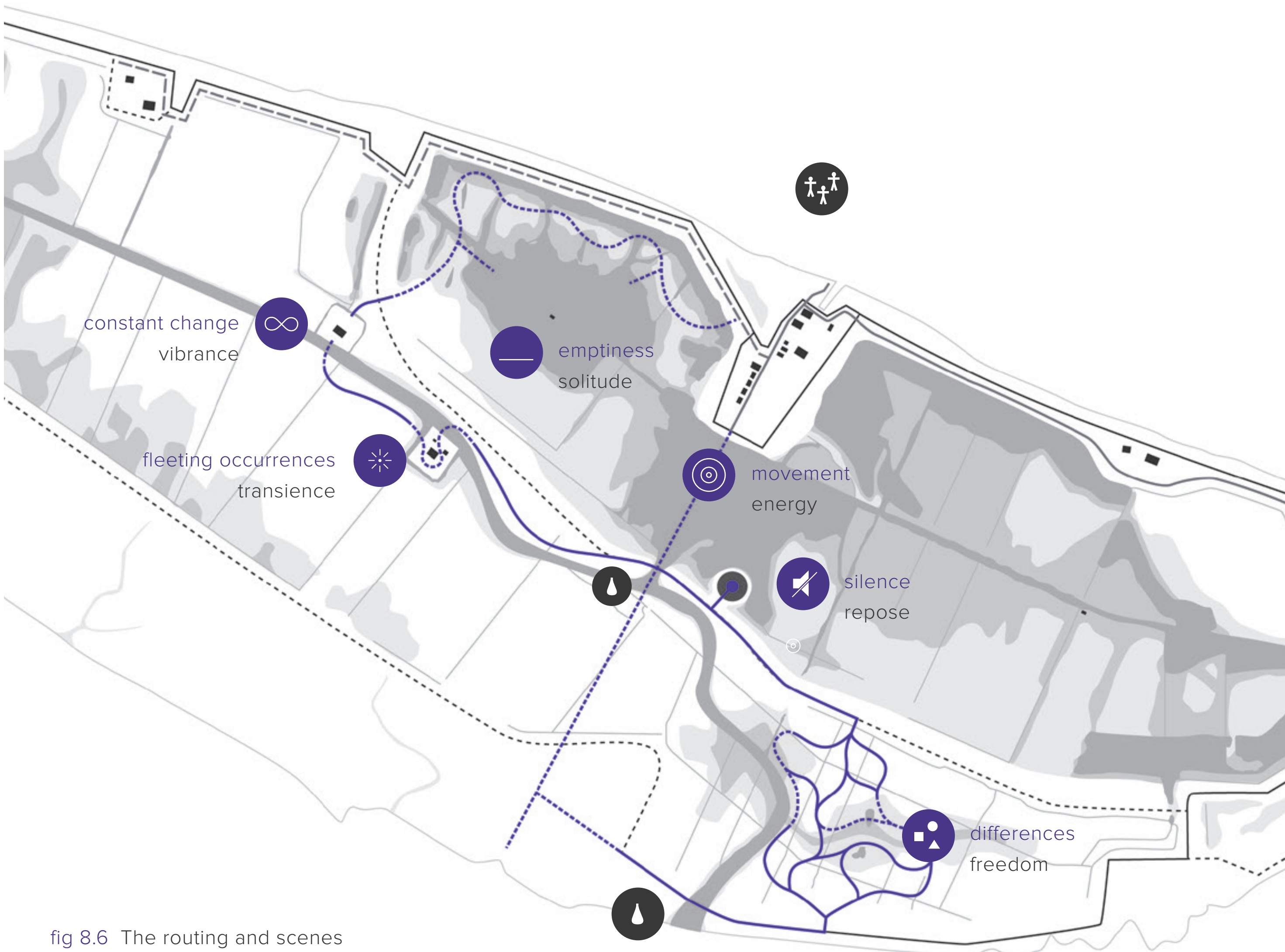


fig 8.6 The routing and scenes

The visitors arrive at the small hamlet of Tiengemeten, from which the road leads to the dyke that surrrounds the hamlet and protects it from the water flowing in and out of the nature reserve. This is where the route really begins.

scene 1: movement

Standing on the dike, the visitor is provided with a first overview of the island's nature reserve. Hundreds of thin, swaying tubes that stand in the water draw in the attention of visitors standing on this dyke. They lure them onto a slightly elevated that crosses the width of the island in one radical straigth movement. Upon entering this path freely exposed to wind and water, the perception of space is immediatly challenged by a choreography of swaying tubes. Responding to the flows of wind and water as well as the movements of the visitors themselves the thin tubes autonoumously bend and change from transparent to opaque. They function as a visual and tactile sensation of a play between these three sources of energy.

water in/outlets

Having crossed the first scene, the visitor comes across two water inlets. A small one, where water flows into and out of the seasonal marsh (the 'Weelde' area), and a large one, where water flows into and out of the island as a whole. Both inlets operate as machines that control the flux of water through sluices (Weelde and island inlet) and a pump system (island inlet). Since the tidal dynamic of the Haringvliet isn't sufficient to create the rare freshwater tidal ecology, these systems create the water dynamic that is required to achieve the desired biodiversity. The systems does not merely respond to water level of the Haringvliet to determine the flow of water onto and of the island, but incorporates the 'mood' set by the weather conditions (sunshine, temperature, precipitation etc.). By doing so it creates a 'stage' for landscape experiences that reflects the ambient atmosphere. The island's inlet serves as the turning point of the route, whereafter the big impression makes place for a subtle experience of the landscape.

scene 2: differences

Leaving the straight line of first part of the route, the visitor is suddenly confronted with choice as the path diverges. The question rises what one wants to see, which focuses the gaze upon the landscape and its diversity. Upon exploration of the meandering paths the visitors crosses a variety of small landscapes; open pastures, reed marshes, pools, the artery creek and groups of shrubbery. In each type of these landscape elements a synthetic scent, adjusted to the type of space, the weather, time of year and the visitors bodily state, is automatically and discretely spread throughout the space. The differences between the types of landscapes are thus emphasized by creating more perceptible olfactory differences.

scene 3: silence

Coming from the quite intensive sensuous experience of the previous scene, the visitor arrives at the hill that, all the while prominently visible, demands to be investigated. When arriving on the hilltop, the visitor comes to a halt and quiets his or her voice; all ambient sound is faded away and leaves nothing but absolute silence. Only calm movement and near-silence will prevent the background noises, that otherwise would almost go unnoticed, from fading back in. The hilltop acts in this scene as a stage that 'emerges above' all ambient sound, creating the possibility for a moment of repose.

scene 4: fleeting occurrences

Coming from the place of silence a simple, slowly sloping upwards wooden deck bends around and leads onto a small island. On this miniature island, formerly a farm courtyard, ruins of an abandoned farm and house create a sense of the transiency of life. A bar railing the elevated path invites to peek over the edge into the tangled overgrowth. Just moments of when you let go of the bar, your own voice emerges from somewhere in the dark shrubbery, only to be fade away in a gust of wind. At unpredictable moments the island blurbs out sound fragments recorder from the moment you stepped onto the ferry, as well as scents from scene two, *differences*. The paths acts as a physical timeline of these past moments, creating the sensation of fleeting occurrences that can't really be placed or influenced.

scene 5: constant change

After crossing the creek for the last time the visitors step inside a space formed by tall and slender trees, with positioned in the middle walls of what was once a potatoe barn. Moving freely through this space a live composition of natural sounds is fabricated and played. In a play between landscape and the visitor this composition changes dynamically and is never the same. The barn ruin taking up such a dominant visual role is juxtaposed with its 'dead' quality through a new type of sensation; upon touching the walls the visitor experiences a tactile sensation reminiscent of a heartbeat. Through these interventions this enclosed space is transformed into lively and vibrant atmosphere.

scene 6: emptiness

The last scene takes the visitors into a subliminal dialogue with emptiness and solitude. Coming from a place of vibrancy the visitor is confronted with a lack of sensations, which emphasizes the emptiness of this scene. In the vast open space of this scene, right in the middle of large water body, a small shed stands as a fragile object exposed to wind and rain. Two piers peek out of reed fields along the edge of the lake and provide a free view towards this object. The visitor itself is putting into the same conditions as the shed, being exposed and surrounded by water. When the silence and emptiness of this place come under stress by being able to see or hear other people, the shed slowly dissolves into thin air, only to reveal itself again when quietude has returned.

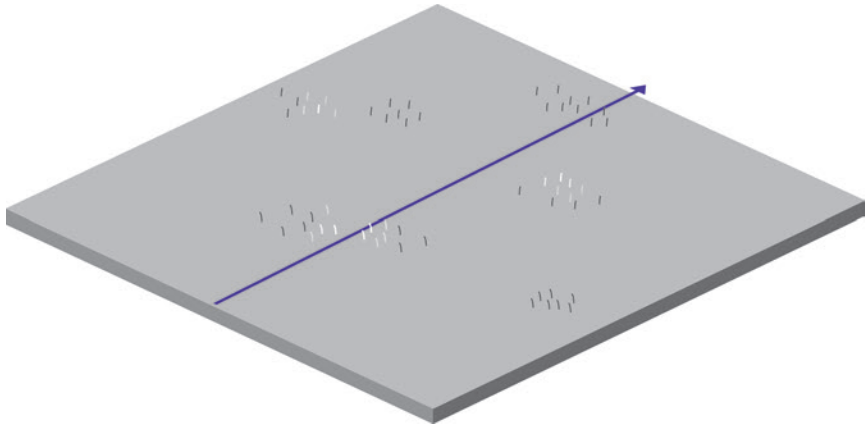
end: ferry crossing

After the last scene the visitor arrivers back again in the hamlet and can choose to return to mainland. On the ferry the intense glow and pulsation of the wristband is replaced with a soothing slow pulse. Back on shore the wristband is deposited, allowing the visitor to disembark the ferry.

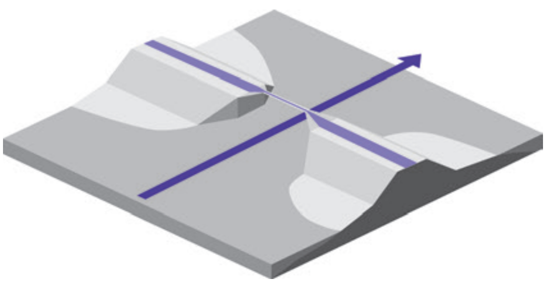
movement (V) (T)

experience of energy

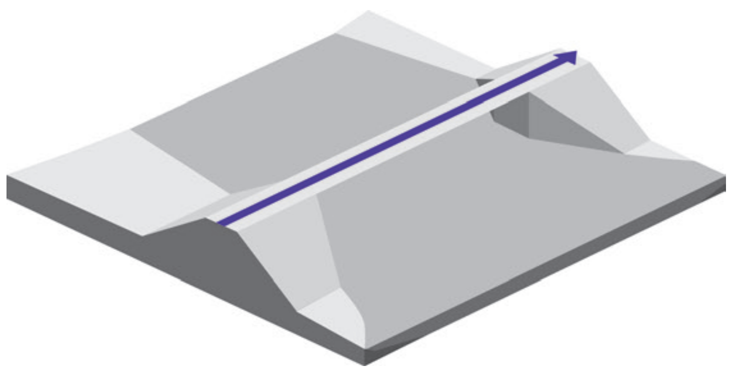
Visual and tactile sensation of the energy of the wind, water current and the visitors themselves, visualised through long, thin flexible tubes that autonomously bend and shift from transparent to opaque.



water in/outlets Weelde



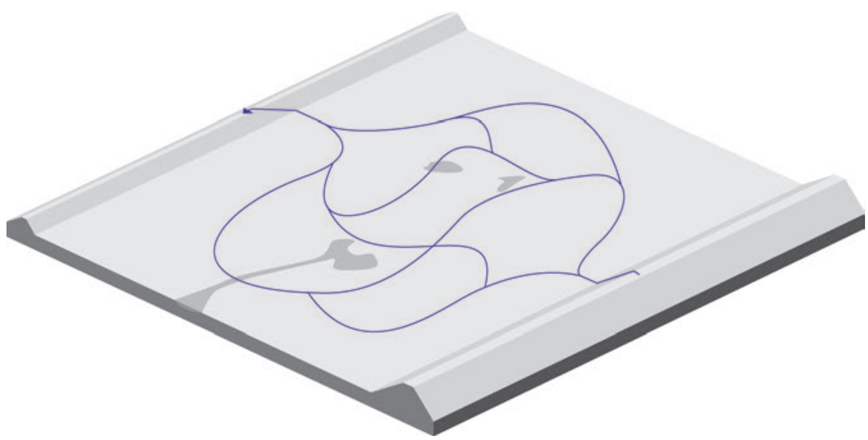
water in/outlet island



difference (O)

experience of freedom

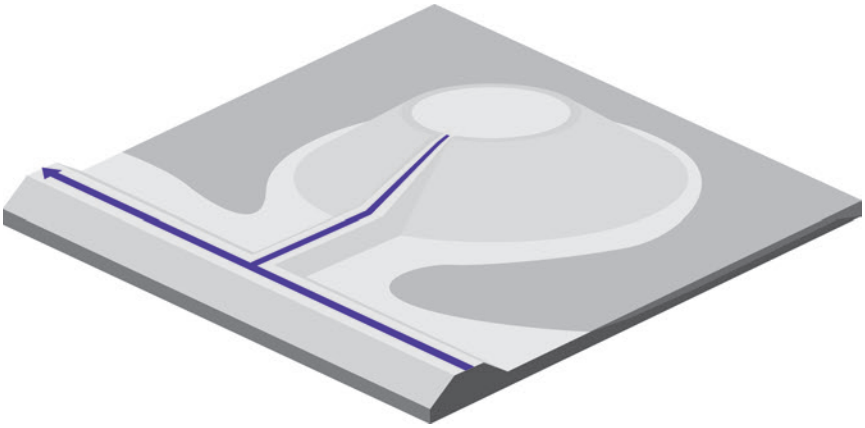
Olfactory sensation of various different synthetic and automatically distributed scents that are customized to suit both context and visitor.



silence (A)

experience of repose

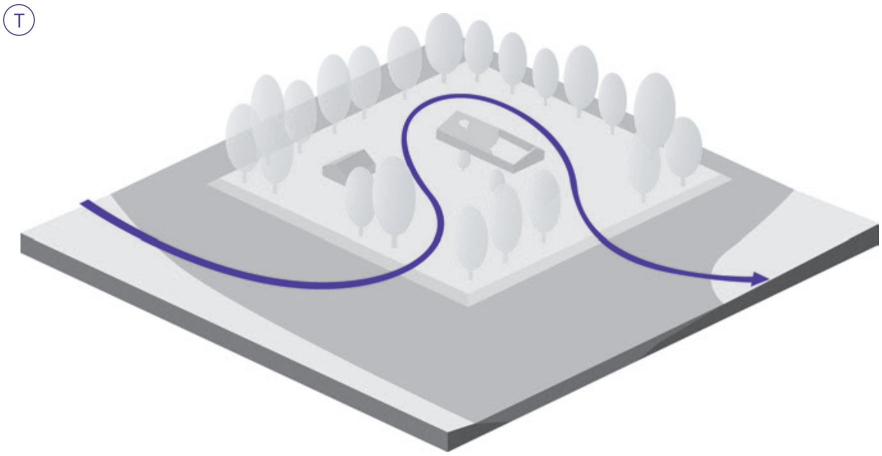
An auditory sensation of ambient sound being faded out (or in) through the use of anti-sound.



fleeting occurrences (O) (A) (T)

experience of transience

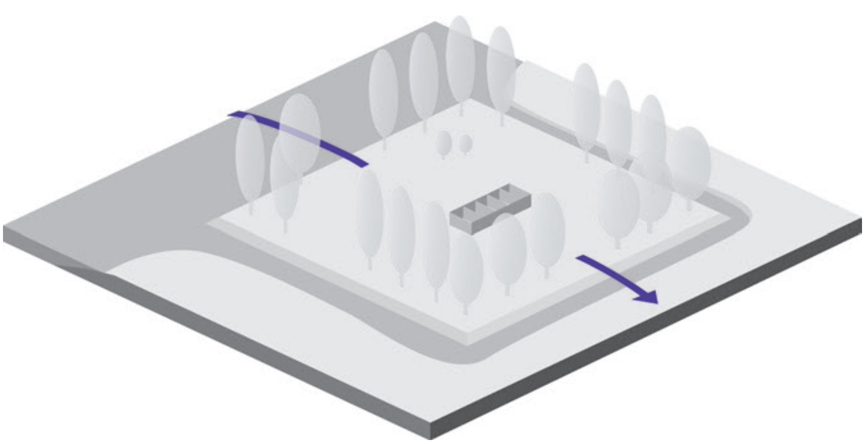
Olfactory, auditory and tactile sensations that refer to previously experienced moments on the route.



constant change (A) (T)

experience of vibrance

Auditory and tactile sensations of the constant changes that are happening in the landscape.



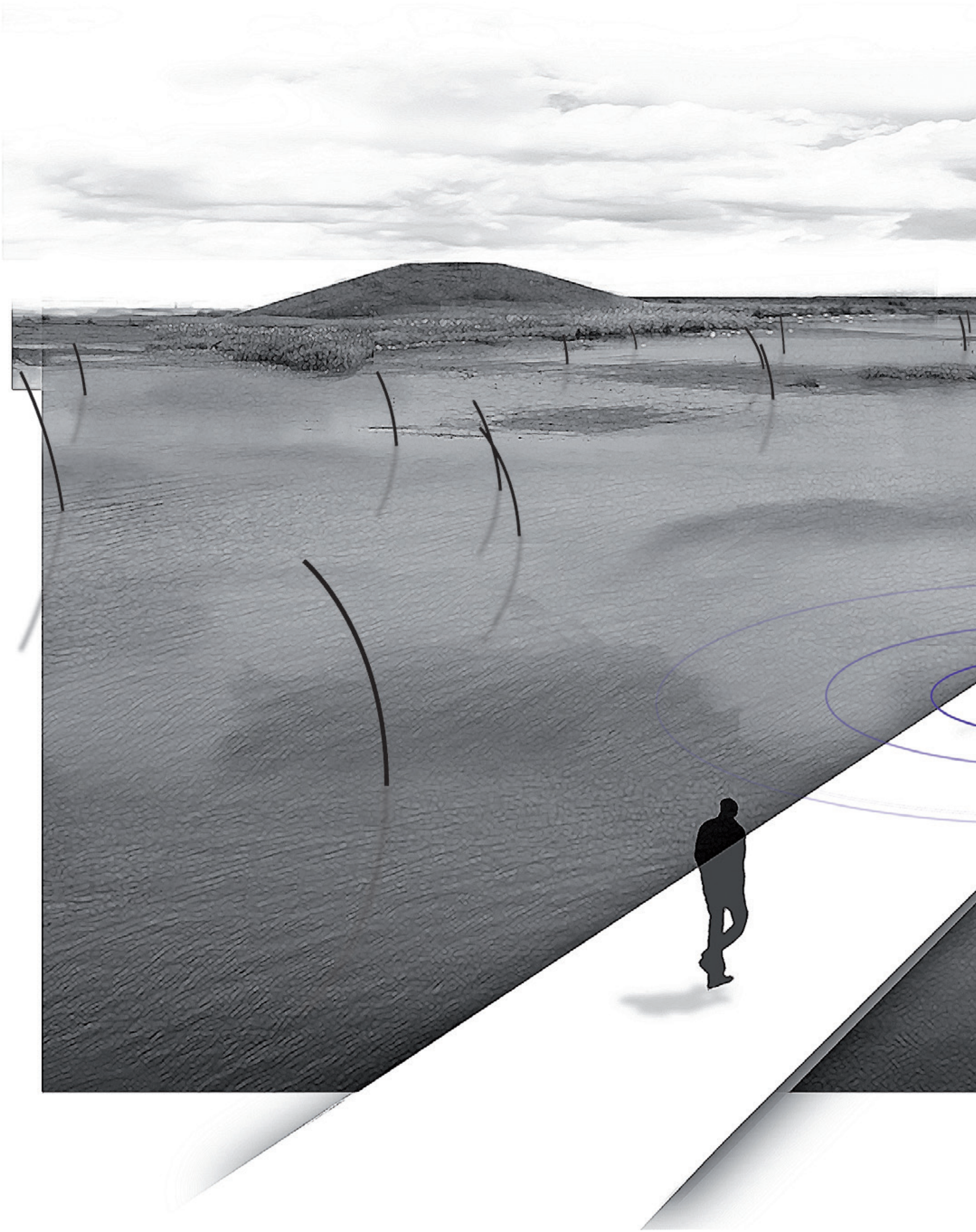
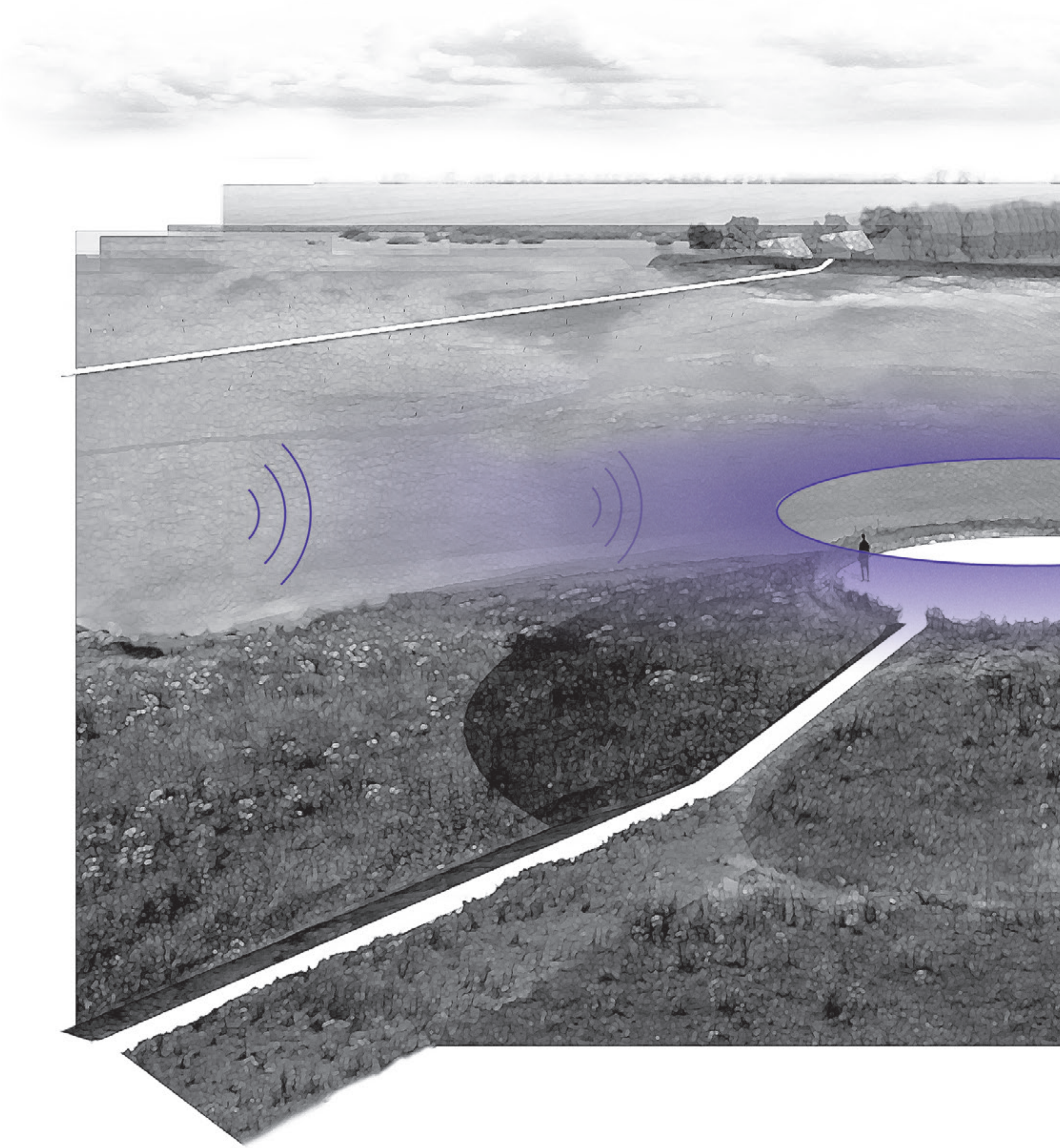


fig 8.7 The 'movement' scene on Tiengemeten as proposed in the design.



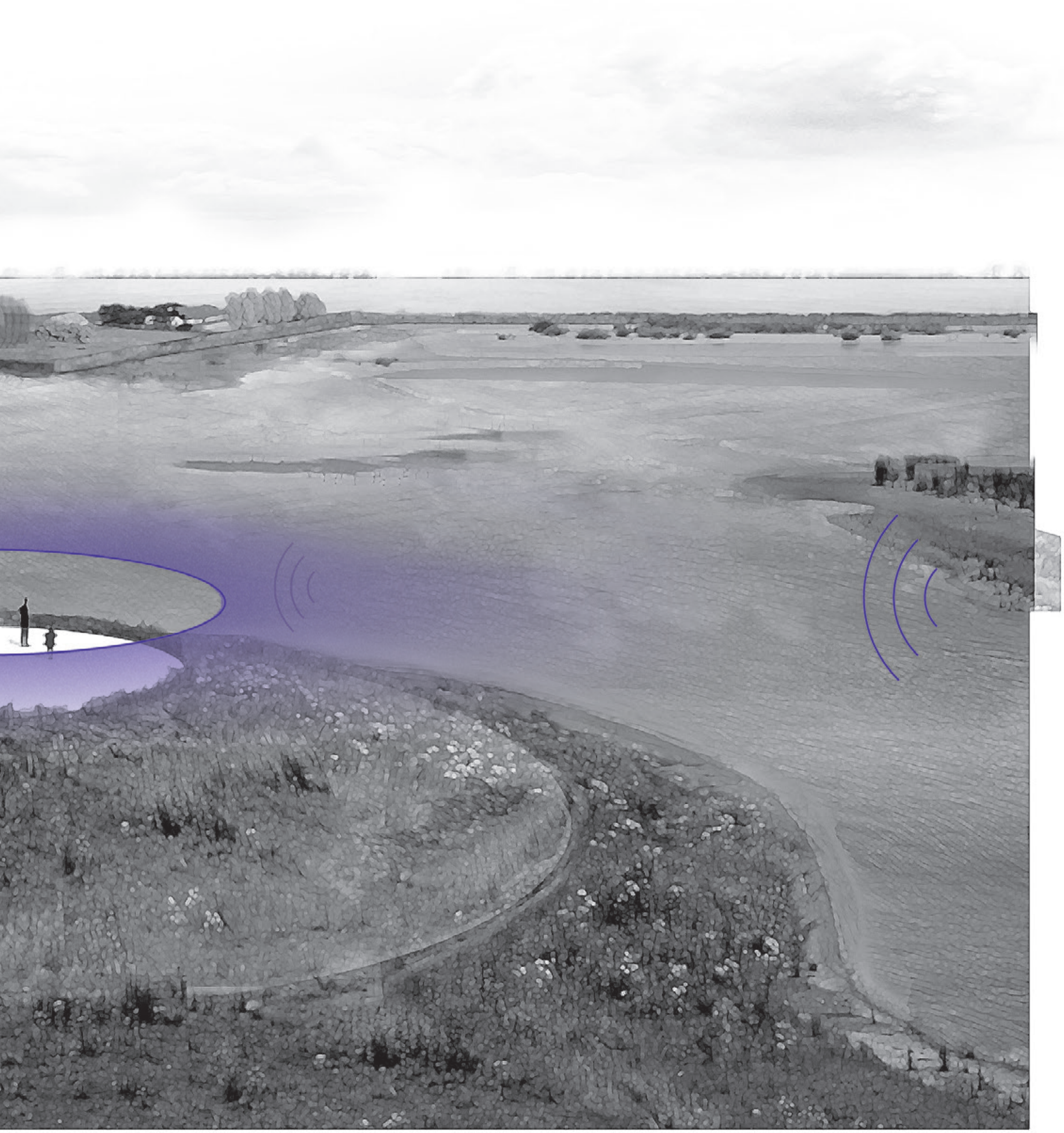


fig 8.8 The ‘silence’ scene on Tiengemeten as proposed in the design.

OUTRO

8 Conclusion

This thesis presented a design method for interactive landscape experiences and a prototype design for the island of Tiengemeten. In this chapter we will first revisit the research questions that enabled the development of the design method. This is followed up by a conclusion on the main question and a discussion of the results. The chapter concludes with two recommendations for further research.

8.1 Results

The objective of this research was to explore a design method for interactive landscape experiences and, by doing so, contribute to the toolset available to landscape architects in design aiming for landscape experiences. In line with the research objective, the main research question was formulated as follows:

By what method could landscape architects design for computer-mediated interactive landscape experiences?

In order to answer this question, three sets of sub-questions were formulated that specified the research challenge; the development of a design method. The first set required a literature study to develop theory on the design for computer-mediated interaction between people and environments, as well as a study of reference projects to deduce relevant design lessons. The second set consisted of a literature review of current theory on the design for landscape experiences. The third and last set of questions related to the integration of this theory on interactive environments into the design for landscape experience.

The answers to these sub-questions will be briefly revisited for a comprehensive overview of the research results. After having considered these, the chapter concludes with an answer to the main research question.

8.1.1 Revisiting the sub-questions

Part I Developing theory on computer-mediated interactive environments

1a How does the pervasive computing concept help understand the design for computer-mediated interaction between people and an environment?

The pervasive computing concept describes a very specific type of computer-mediated interaction between people and environments. A literature study led to a definition of the concept in order to understand what this type of interaction is and of what components it is constructed. In this thesis, pervasive computing is defined as a concept of computer-mediated *interaction* between people and an environment; this interaction is facilitated by a perceptive, interpretive and reactive *technological system*, sited and situated in a specific *context of use* in which the system's *interface* is embedded physically, procedurally, and socially. The four components of this definition form a checklist that can be used when designing for interactive environments that offer the type of interaction as it is envisioned in the pervasive computing concept.

1b How does the theory of affordances by GIBSON (1977) help in understanding what landscape architects can design of computer-mediated interactions between people and an environment?

The theory of affordances is an ecological approach to the behaviour of people, stating that affordances are latent action-possibilities defined by the physical properties of an object or environment taken in reference to an actor. Because 'traditional' affordances are limited to environments that offer only action-possibilities, this thesis introduced the concept of *'smart' affordances* to include interaction-possibilities.

These interaction-possibilities are built upon *interface*- and *environment operators* and *signifiers*. Interface operators are features of the environment that facilitate the input for the technological system, while environment operators are features that make the interaction operable. SIgnifiers are the physical and ambient changes in the environment produced by the reactive system and (dependent of design) the features that enable the user to create an understanding of the relationships between the input actions and the output.

Operators and signifiers are physical and ambient features of the interactive environment. If this environment is in a landscape architectural setting, the design of these operators and signifiers can considered to be a concern of the landscape architect.

1c What design lessons can be derived from reference projects and expertise knowledge, and how do these relate to the concept of pervasive computing?

The study of current practices consisted of an analysis of nine reference projects and a review of writings by and a lecture of experts on the design of interactive environments. From this study a total of nine fundamental design lessons were derived. These lessons were linked back to the components of pervasive computing (question 1a) and the operator and signifier concepts from the theory of affordances (question 1b). By doing so we created a better understanding of the use of these components and the operator and signifier concept in the design process. The design lessons itself can be used as guidelines when designing interactive environments.

Part II Current theory relevant to the design for landscape experience

2a How does the theory on landscape experience by JACOBS (2006) explain landscape experience and the design for landscape experience?

The theory by Jacobs explains landscape experiences as personal and variable constructs of the brain, formed by inputs of the sensory organs and the condition of the bodily states and processes. Because of the involvement of the subject's body and brain in the construction process, it is not possible to design landscape experiences. However, landscape experiences are derived from the sensory perception of the physical and ambient landscape, resulting in visual, tactile, auditory, olfactory and gustatory *sensations*.

The literature review of Jacobs' theory revealed that landscape architects can employ these sensations in the design *for* landscape experiences. Though sensations may not be attentively perceived by everyone, they are universal and as such make for a very precise and easy to communicate design goal.

2b How does the theory of conceptual metaphor by Lakoff & Johnson (1980) explain the design for landscape experience as the design of physical and ambient landscape features?

Lakoff & Johnson's theory of conceptual metaphor presented the metaphor as a means to understanding one idea, or conceptual domain, in terms of another. Metaphors can be abstract or refer directly to a physical or ambient feature of the environment. The literature review revealed that this proporty of conceptual metaphors is helpful in bridging the gap between the definition of a desired landscape experience and the design of sensations.

In order to identify sensations that are associated with the desired landscape experience, we can use metaphors for this experience and link these to physical and ambient features of the landscape. As a result, landscape architects can design 'amplified' sensations that refer through their metaphorical meaning to the desired landscape experience.

Part III Linking pervasive computing with design for landscape experience

3 How does design for computer-mediated interactions between people and landscape relate to design for landscape experience?

The design method for interactive environments and the design method for landscape experience show three points of overlap:

A. The aim or purpose of design

In the literature review of Jacobs' theory on landscape experience we identified the design of sensations as a way to design for a desired landscape experience. With the introduction of pervasive computing in the design, these sensations can be made 'dynamic' –meaning that they change over the course of an interaction between people and an environment. In essence, these dynamic sensations are the method of communication for the computer-mediated environment: the output of the technological system and the signifier of the interaction. Whereas the design method for interactive environments asked for a purpose of the interaction, the design method for landscape experiences provided one: sensations. The concept of dynamic sensations thus ties the design of interactive environments seamlessly together with the design for landscape experiences.

B. The delineation of the working space

The second point of overlap is the similarity between the *context of use*, from the design method of interactive environments, and the *'scene'*, from the design method for landscape experience. Whereas the scene is a systematically delineated space based upon an analysis of the desired landscape experience, the context of use is more fluid in its definition. Both are nonetheless compatible, as they are in essence about the working space. The combination of the two results in a systematical delineation of the site and situation of the interactive landscape experience.

C. The selection of the key elements of design

In the study on pervasive computing we defined interaction *elements* as keys in the design of interactive environments. The selection of these elements from the context of use, as well as the introduction of new elements, happens in accordance with the purpose of the interaction. In the design method for landscape experience we suggested to make a selection of physical and ambient key features, based upon their strong metaphoric reference to the desired landscape experience. Both selection processes can be merged by taking the key features selected for their metaphoric reference as key elements for the interaction.

8.1.2 Main conclusion

The synthesis made in answering the last research question made it possible to develop an integral design method aiming for interactive landscape experiences (see chapter 6). This method consists of three phases:

1. The *analysis phase*, in which the desired landscape experience is formulated as linguistic concept and deconstructed into conceptual metaphors. The working space (scene, or context of use) is defined by linking these metaphors to physical and ambient features of the landscape.
2. The *possibilities phase*, in which the purpose of the interaction, being the dynamic sensation(s), is determined. Based upon the purpose, possible selections of key features (or interaction elements) and design interventions are explored and defined.
3. The *design phase*, in which the interaction and the interactive environment are designed. Relationships between the interaction elements are constructed in order to select the element(s) that will create the dynamic sensation(s). The sensation is then designed along with the interface and the basics of the technological system (the dynamic input criteria and software patterns).

The eleven steps taken over the course of these three phases lead to the design of a dynamic landscape sensation that faciltates an interactive landscape experience. The method as a whole is in line with Vroom's (2006: 98) definition of a design method, being a systematic plan for the design of a particular thing and consisting out of a series of successive phases, all involving a number of decisions based on deduction (the rational component; the analysis phase) and on inductive jumps (the intuitive or creative component; the possibilities and design phase).

In the process of testing the design method, not everything was as straightforward as the method may imply. First of all, the method requires positioning in a design context. In the test case this was the design of (1) a linear routing that (2) directs visitors through a serie of distinct scenes and (3) is located on a island, in a nature reserve. This step of formulating the design context can be considered to be step 0 of the method. A second issue of the design method is that it seems to be more difficult to apply for purely immaterial, ambient landscape sensations. This became apparent in the process of designing scene two, about the olfactory sensation of 'differences', and can be ascribed to its focus on taking prominent existing features of the environment as a point of departure. Lastly, the method seems equally less straightforward in its use when designing complex interactions such as in scene four, about the auditory, olfactory and in part also tactile sensation of 'fleeting occurences'. This however may as well be due to the overall complexity of this particular scene, in which design lesson two (see chapter 4) may not be taken seriously enough: 'lightweight interactions are fun interactions, complexity kills'.

To conclude, the augmentation of pervasive computing in landscape and the creation of interactive environments results in an expansion of the design tools available in the design of sensations for landscape experiences. The design of 'amplified' sensations as presented in the basic design method for landscape experience (see chapter 5) provides the landscape architect only with so many 'knobs and levers', mostly focused on the form and substance (physical features) and the visual appearance (ambient features) of the sensation. With the introduction of pervasive computing the amount and type of knobs and levers appears to be increased significantly, making 'dynamic' sensations possible. The embedding of computer technology into the landscape provides the landscape architect with more ways to design or influence the ambient features of landscape. This is due to the sheer amount of ways in which computer technology can be employed. One can image that, as the development of computer technology keeps progressing, the possibilities of its use will only increase.

8.2 Discussion

8.2.1 Design method in development

The design method presented in this thesis is without question a method that is in the stage of development. A test case design functioned as a first validation of its soundness. This test consisted of six scenes for each of which the design method was applied. More tests in a diverse range of design contexts, including urban contexts, are however needed to validate its overall applicability.

We can identify two other weaknesses in this research, other than the uncertainty regarding the method's general validity and usefulness. The first is the definition of the pervasive computing and its components as presented in this thesis. This definition is based upon a multitude of sources from a variety of research domains, including the Human-Computer Interaction domain (e.g. Weiser), Architecture domain (e.g. McCullough) and the Philosophy domain (e.g. Galloway). Because of this variety, the definition may conflict with feature description of pervasive computing provided by other authors. Such conflicts may exist because of the lens through which the concept is studied. This thesis aims on the comprehension of the concept's relevance to landscape architects, which inevitably places the focus on the physical and ambient manifestations of pervasive computing that can be designed. Even though this focus may have subliminally directed the literature study, it is important to understand that the original writings of Weiser on the concept served without exception as a baseline for the verification of findings from other literature.

The other potential weakness of the research could be the integration of interactive environments in the theory of affordance by Gibson. To be precise; the positioning of the interface as intermediary between the user and the interactive environment. The interface is one of the most abstract components of pervasive computing, making it difficult to fully comprehend and delimit its scope. This was reflected in the design process of the test case, in which uncertainty arose at times about the distinction of interface operator and environment operator. This issue is food for further thought, as suggested in the last paragraph on recommendations.

8.2.2 Perspective on landscape architecture

This research revealed that the design of interactive environments, or more precisely, the design of interactive *landscapes* and *dynamic sensations*, can be of concern to landscape architecture practice. We have found that interactions as envisioned in the pervasive computing concept are heavily grounded in their context of use. This particular characteristic is arguably precisely what makes this concept so suitable for use in landscape architecture, which itself is chiefly concerned with the design of contexts.

Whereas landscape architects 'traditionally' design for contexts that offer action-possibilities, the introduction of pervasive computing creates an opportunity to design for interaction-possibilities. This type of design can be seen as a specialisation in landscape architecture practice and research, positioned somewhere inbetween the Landscape Architecture domain and the Human-Computer Interaction domain. Because of its 'custom-built' characteristic, the design of interactive environments requires an interdisciplinary design approach that includes technology developers, software programmers, and hardware programmers in the design process. The formulation of the input criteria, software patterns and output could function as the bridge between landscape architecture and the technical disciplines.

Apart from this practical perspective on the design of interactive landscapes and dynamic sensations, we can also consider the more user-oriented perspective on this development. Gazing into the future, interactive landscape experiences could transform our perception and expectations of landscape. However, before we arrive at that point we will likely first see a transition phase in which the novelty of the phenomenon gradually wears of and people come to see its presence as 'only natural'. Examples hereof are the introduction of electricity, the internet and the smartphone. Because interactive environments are at this point in time near to nonexistent, or at the least far from common practice, encountering such a landscape would be an exceptional experience that starkly contrasts with everyday life. The attention that accompanies this novelty is an issue of which designers should be well-aware, as it is likely to impact the user's experience of the environment and interaction.

8.2.3 Contribution to the Landscape Machine Design Lab

The research presented in this thesis was conducted as part of the Landscape Machine Design Lab of the Wageningen University Landscape Architecture chair group (see chapter 1, paragraph 1.1). This thesis explored the possibilities of a technology-augmented 'living' landscapes from the perspective of aesthetics and narration, and in doing so contributes to the conceptualisation of landscape machines.

According to Roncken (2012), a landscape machine is first and foremost a productive landscape that addresses an existing malfunction in the landscape. Secondly, the natural processes of the landscape are stimulated in order to improve the input-output ratio. Lastly, a landscape machine is not 'made', but rather developed in different stages: the stage of initiation, a growth state, and a yield stage. If 'productive landscape' is interpreted in the broadest possible sense, this thesis can be included in the landscape machine concept as a machine that 'produces' dynamic landscape sensations. The integration of pervasive computing into the landscape creates a situation in which natural (and non-natural) phenomenons are emphasized by augmentating these with dynamic sensations –improving the 'input-output ratio'. Though this type of landscape is obviously 100 percent man-made, it does have similarities with the three stages. The initial stage is the employment of the design, the growth stage is the fine-tuning of the interactions, and the yield stage can be considered to be the point at which the interactions reach an 'optimum' effect.

The interpretation of the landscape machine concept in such broad terms as here raises the question whether it aims to be too inclusive. In doing so it could lose its effectiveness in describing a type of landscape design that is fully commited to the improvement of *natural* processes, creating maximum yields with a minimum of input. It could be that other flavours of the pervasive computing concept do provide tools for this type of design.

8.3 Recommendations

As explained in the main conclusion, the design method presented in this thesis should be considered a method in development. Further research is needed to verify its usefulness, its wider applicability and overall soundness. There can be identified two research topics which would contribute most significantly to the current design method, being (1) the interface in relation to interface operators and environment operators, and (2) the process of translating design ideas of the interaction into dynamic input criteria and software patterns for the interpretive system's algorithms. Research on the first topic would contribute to a better comprehension of how operators can be utilized in the design of interfaces. Research on the second topic would help bridging the gap between landscape architecture design practice and the technical disciplines. These disciplines develop the technological systems that make the interactive environments actually possible, so a seamless transistion from design to hardware and software seems crucial. Though there are other research topics imaginable to improve upon the design method, these two should help propel its practical usefulness and –what is most hoped for– lead to the development of computer-augmented landscapes that offer truly interactive experiences.

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4.1 Norbert Aepli, http://en.wikipedia.org/wiki/Diller_Scofidio_%2B_Renfro
4.2 Studio Roosegaarde, http://www.studioroosegaarde.net/

Appendix I Glossary

Action-possibility	Actions afforded to a user by the static features of an environment and the perception, knowledge, and capabilities of the user.
Ambient features	Features of the environment perceptible through whichever one of the senses.
Affordance	Latent action- possibilities defined by the physical properties of an object or environment taken in reference to an actor.
Algorithms	Procedures or recipes for complex and automated calculation, data processing, and reasoning, making pervasive computing capable of true interaction.
Conceptual metaphor	Refers to the understanding of one idea, or conceptual domain, in terms of another.
Context of use	The site and situation in which an interaction takes place.
Cognitive affordance	Perceived action-possibilities that can be either true or false.
Dynamic sensation	Sensory perceptible features of an environment that, due to the implementation of pervasive computing, change through the course of an interaction between people and the environment.
Environment operators	The physical features facilitating the interaction- possibility from within the interactive environment.
Interaction	Deliberation over the exchange of messages; when the message sent back is affected by the message received does interaction occur. Put differently, a reaction is a monologue and an interaction a dialogue. This is translated to interactive technology by McCullough (2004: 20): *"Only when technology makes deliberative and variable response to each in a series of exchanges is it at all interactive."*
Interaction elements	The combined physical and ambient features that make up the interaction, and can be either already existent or purposefully introduced.
Interaction-possibility	Interactions afforded to a user by the dynamic features of an environment and the perception, knowledge, and capabilities of the user.

Interaction relationships	The way in which the interaction elements are linked or related to eachother in the interaction.
Interface	All means by which the users provides input for the interactive environment. It consists of the users' body (e.g. voice, heartbeat, movement), their movement through space, and their actions with interaction elements (e.g. touching).
Interface operators	The features facilitating the input for the interaction.
Interpretive system	The hardware and software that processes raw data from the perceptive system into meaningful information with the use of algorithms.
Input criteria	A numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation.
Landscape experience	Personal and variable constructs of the brain derived from an interplay between sensations of the world and states and processes of the own body.
Linguistic concepts	Abstract mental constructs of the brain that translate experience into language.
Operators	The specific physical features facilitating an action-possibility.
Perceptive system	The collection of hardware (e.g. sensors) and software (e.g. data crawlers) technologies that work on extensive data acquisition. The hardware is focused on gathering data from the context of use (being the interface and ambient environment) while the software scours existing digital data outside of the physical domain.
Pervasive computing	A concept of computer-mediated interaction between people and an environment, involving a perceptive, interpretive and reactive technological system that is sited and situated in a specific context of use, in which the system's interface is embedded physically, procedurally, and socially, to mediate interactions between people and environment.
Physical affordance	Physical actions afforded to a user by the features of an environment and the perception, knowledge, and capabilities of the user.

Physical features	Features of the environment that are visually and tactilely perceptible.
Physical interface / embedding	The use of peoples' body, their movement through space, and their actions with objects as interface.
Procedural embedding	The use of behaviours common to the context of use as interface inputs.
Reactive system	The hardware technologies that transforms the commands of the interpretive system into physical or ambient changes of the environment. The reactive system produces visual, tactile, auditory, olfactory and/or gustatory effects that can be registered by the human senses.
Sensation	Visual, tactile, auditory, olfactory and/or gustatory stimuli picked up by the sensory organs, forming an input for the construction of experiences.
Signifiers	The specific ambient features that facilitate the perception of an action-possibility.
Site (context of use)	A finite physical space in which the interaction takes place.
Situation (context of use)	The type of space and the elementary actions in which its users are engaged (McCullough 2007).
Social embedding	The use of associative design or design conventions in order to communicate to the user how he or she can actually provide input for the interaction.
Software pattern	A formulation of a problem, the solution, when to apply the solution, and what its consequences are.
Technological system	The hardware and software infrastructures that make otherwise passive environments able to interact.

Appendix II Reference projects

1. Ampel Pong

Mereaia Suberina / suberinaworks.
Concept, prototype was developed

Interaction	
Purpose	To transform waiting at a crossing into a playful experience
Elements	The pedestrians, the crossing, cars
Relationships	The pedestrians and cars influence the projection of a game upon the crossing
Context of use	
Site	A pedestrian crossing with traffic lights
Situation	A public space where users wait on opposite sides of a demarcated space
Interface	
Physical interface	The user's body operates as interface
Procedural embedding	The interaction is embedded into waiting and standing at a crossing
Social embedding	The interaction employs a game of which the rules are widely known
Technological system	
Perceptive system	Tracking positions of pedestrians and cars
Interpretive system	Translation of number of pedestrians into number of play elements and position of the ball
Reactive system	Play elements are projected upon the street

2. ADA: living building

Swiss national exhibition EXPO.02.

Executed

Interaction	
Purpose	To create an experience of a 'living' building that offers play elements
Elements	The visitor, the building and its sounds and lights
Relationships	The visitor walk through and position in the building is linked with actions of the building
Context of use	
Site	A dedicated building with multiple rooms and audio-visual installations
Situation	An EXPO pavilion that is visited for exploration and experience
Interface	
Physical interface	The users movement through space
Procedural embedding	The interaction is embedded in the activity of walking, or in this case, exploring
Social embedding	The interaction employs associative design through sounds and pointed lights
Technological system	
Perceptive system	The long-term tracking of user's position
Interpretive system	The correlation of users' movement patterns with system directions
Reactive system	The system responds through sounds and lighting effects

3. Sonic City

Ramia Maze and Margot Jacobs, 2002-2004

Executed

Interaction	
Purpose	A auditory, musical sensation of the environment through which the user moves
Elements	The user, a coat, the environment
Relationships	By moving through space, the coat picks up features of the environment and creates ‘music’
Context of use	
Site	Not bound to a specific site, yet taking the environment as main input
Situation	Any space where the user can walk
Interface	
Physical interface	The user’s movement through space acts as interface
Procedural embedding	The interaction is embedded in the activity of walking
Social embedding	The music generated by the interaction is primarily associatable with the speed of walking
Technological system	
Perceptive system	A coat that has a metal detector, proximity and light sensors, a microphone and accelerometer
Interpretive system	The real-time context-based generation of music
Reactive system	The output is ‘music’ that is played through headphones

Computer technology is becoming smaller and more powerful by the year, resulting in the continuous emergence of new possibilities for its use. One of such possibilities is the embedding of technology into our landscapes to enable interactions between people and the landscape. This thesis takes this development as point of departure and explores its potential in one of the core tasks of landscape architects: the design for rich and immersive landscape experiences.

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