WindO: Exploring the Use of Body Scale Shape-Changing Interfaces in Urban Environments

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Concept video: http://tinyurl.com/ConceptWindO

ABSTRACT
In this paper we explore the use of body scale shape-changing interfaces to increase use and amenity of urban environments. In order to do this, we made the prototype WindO; a body scale construction, which can invite people to use it by opening towards them, allow them to control it with a control board and cover for the wind dynamically in response to change in wind direction. This was done through shape-changing interfaces that have the ability to dynamically adapt their forms in response to input, leaving numerous possibilities for practical use. From two evaluations, one in a controlled environment and one in an uncontrolled environment, we found that people were uncomfortable with indirect interaction in body scale shape-changing interfaces but they enjoyed direct interaction.

ACM Classification Keywords
H.5.2. User Interfaces

Author Keywords
Shape-Changing interfaces; Urban Spaces; Body Scale; User Experience

INTRODUCTION
Being outside in the nature and in open urban areas plays a vital role in human health and well-being[13], but in cities the nature is often far away and the urban areas are not always comfortable to stay in. Urban spaces are often wide open with no cover for wind or rain. An important factor on how comfortable outdoor urban spaces are, is the weather. In northern countries people are mostly seen on the benches around the urban spaces when the sun is shining and the wind is gentle. Such weather condition is however not the most common in the northern climate. The weather is always dynamic and can shift frequently, changing a calm morning into a windy afternoon. In *How to Study Public Life*[4] Jan Gehl argues that another important factor influencing how the urban spaces are used is the design of buildings and space in a human scale. This amenity value of Gehl suggest the design relates to how people sense and experience the urban space, favouring spaces that support comfort for people and protects them from uncomfortable sensory stimulation.

To combat the changes in weather we have looked to the dynamics of shape-change. Shape-changing interfaces have many possibilities in their hedonic and functional purposes. They can move dynamically in response to different inputs and are thereby able to represent digital information in as many ways as the output can show through transformations. This is an area of research still being looked into. Most research on shape-change has been done in sizes that appropriate the hand and into the possibilities of affecting users on an emotional level.

Based on observations and interviews of people at urban spaces in Aarhus, we have designed different concepts to explore body scale shape-change. Starting with designs that protected the user from both wind and rain, we delimited the problem to only cover wind. We chose to focus upon wind because it varies in direction and force in contradiction to rain, that requires either cover or no cover.

This paper will present the concept of WindO (see figure 1); a body scale shape-changing system to explore how shape-change can be used to make outdoor urban spaces more attractive and enjoyable all year round.

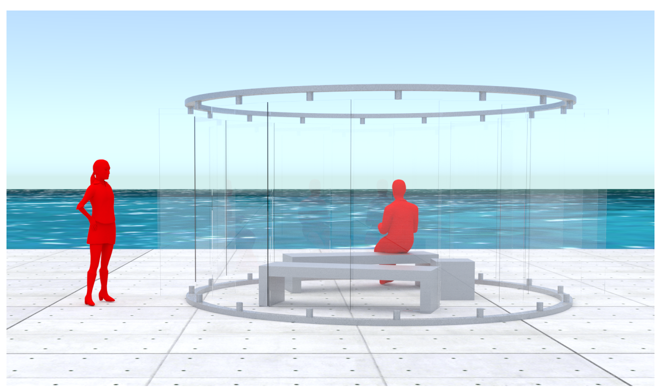


Figure 1: The WindO concept

RELATED WORK
Examples of shape-changing interfaces are numerous, such as mobile phones[6], faucets[12] and voice recorders[14]. This new kind of interface has been and is being explored within HCI communities around the world.

Living interfaces: the thrifty faucet [12] is an experiment on how Human-Machine Interaction can benefit from physical interfaces with life-like movements. The experiment is done by approaching the problem of sustainability in regards to helping users being aware of their water consumption through living interfaces. They create the prototype called the Thrifty Faucet, a water dispenser with focus on imitating bodily behaviour. From a pilot study the paper concludes that the prototype made the test persons curious about interacting with it and triggered emotional reactions from fright to amusement. They conclude that this indicate it might be means to help user be aware of their water consumption.

In *Shape-Changing Mobiles*[6] Hemmert et al. investigates users perceived affordance of the dynamics in shape-changing interfaces. In their experiments they are able to conclude that users can perceive dynamic affordances of angles in shape-changing back plates of the mobile as accurate as 5 degrees. They furthermore highlight that shape-changing interfaces are more attractive to the users than weight-change in their tests. We find the exploration of functional aim regarding dynamic affordances useful to our evaluations of how users perceive interactions.

In the field of shape-changing interfaces few studies have been done with the functional aim of making practical solutions. *Inflatable Mouse*[8] is an example of shape-change used as a practical solution for a pointing device with high portability and without a slim form factor. The Inflatable Mouse prototype is created to use the ability from balloons to change volume. On the implementational level the mouse can sense when it is pressed, provide haptic feedback through change in volume, provide bi-directional interaction as the user can press it anywhere and be an output channel as well. Other potential applications are presented along with an exploratory user study. The mouse succeeds in its primary task but the air pressure sensors causes some difficulty in practical use of the mouse.

While most shape-changing interfaces have been implemented in sizes appropriating to the hand or other isolated parts of the body, recent research has been looking into shape-changing interfaces in body scale. Examples of this is shape-changing architectural installations like the Muscle Projects, a concept for buildings that are organic ever-changing vehicles for processing and displaying information. These buildings exhibit independent real-time behaviour, like adjustments in shape and response to changing environmental circumstances such as weather conditions[9]. Another shape changing interface in body scale is the coMotion bench[5]. In this study Groenvall et al. use a shape changing bench with indirect interaction to explore how shape-change can improve social interaction. They do this through projecting its form visually and tactically in the shape change. The bench shape-change depending on how users position themselves and their proximity to other users on the bench. Throughout the whole project they explore how users experience body scale shape-change in the wild. The results being, that shape-change caused commotion with the users, because they were not aware of its inner workings.

In urban computing different challenges occur which we should take into consideration when designing for outdoor urban spaces. In *Designing Urban Media Façades: Cases and Challenges*[2], Peter Dalsgaard and Kim Halskov identifies eight challenges when designing for media façades in cities. Some of these challenges include that increased robustness and stability is demanded since designers have no influence on for example shifting weather. Another challenge is the wide variety of situations occurring in cities. The same urban space can be used for both cycling, arriving to a concert, taking a walk, or sports events.

In Denmark there has been long tradition for research in cities for people [11]. Gehl has with his research into improving urban spaces mapped what he calls amenity values [3]. These are his recommendations for improving urban spaces to not only accommodate people but also attract and appeal to the use of these spaces. The weather has a big influence on the use of urban spaces. Throughout the whole year, the spaces invite people to use them for necessary activities as well as optional activities, such as social ones[3, p. 31]. Where people use the urban spaces for necessary activities in all kinds of weather that permits it, the optional ones only exist in good conditions.

SHAPE-CHANGING INTERFACES

Shape-changing interfaces aim at using the quality of objects to change shape to improve upon the interaction with information. By defining the different kind of shape-change that exist, we are able to get a better understanding of how and for what purpose it can be used. Through types of interaction we can also look into how users react accordingly to shape-change.

Interaction

Shape-changing interface make use of physical transformation as input and output. According to Rasmussen et al.[10] they can be sorted in three approaches to interaction.

- No interaction - where shape change is solely used for output
- Indirect interaction - where shape change happens by implicit input from the user or other, such as wind.
- Direct interaction where shape change is used as both input and output

Types of change in shape

Rasmussen et al.[10] categorise the different types of shape-change as change in orientation, form, volume, texture, viscosity, spatiality, addition/subtraction, and permeability. The first six types are topological equivalent, their shapes can pass from one form to another through continuous deformation, without dividing or joining elements. The last two types are non-topologically equivalent, these are rarely used in interfaces because of the few materials able to produce the effect.

Types of transformation

Transformation describe the phases between start and end of the states of the interface. They are characterised by kinetic and expressive parameters [10]. Kinetic parameters are physical aspect of the transformation such as speed, tempo, and frequency. Expressive parameters deal with how the effect of the kinetics is experienced or understood. They are further divided into associations and adjectives. Adjectives describes types of qualities attributed to the movement of the shape change, associations are generated by the transformation and refer to how the user perceive the motion.

Purpose in shape change

There has been found four main purpose categories of using changing shape in research into shape-change: functional, hedonic, explorative and toolkit-supplying[10]. Many interfaces address more than one purpose. Functional purposes include interfaces: to communicate information, as having dynamic affordances, giving haptic feedback, being for practical use or for construction where the user are able to manipulate the interface into a construction of their own. Hedonic aim purposes deals with shape-changing interfaces that engender emotions, look into aesthetic aims or stimulation or provocation used as a design tool for the designers goal. Toolkit-supplying interfaces for helping to design shape-change and Explorative purposes for conceptual experimenting with shape-changing materials and technologies.

EMPIRICAL WORK

To explore our research problem, we have collected data from two urban spaces in Aarhus. The following section will explain the data gathering methods used during the process and the knowledge drawn from the results obtained. Three different data collection situations has been used:

- Observations at a town square in Aarhus, Store Torv
- Semi-structured interviews at Store Torv
- Observations at Dokk1, an urban area by Aarhus harbor (See figure 2)

Figure 2: The waterfront area around Dokk1

Observation at Store Torv

Early in our process we went to Store Torv in Aarhus, which was our initial design setting. Three hours of observations were carried out to map the use of the urban space, especially with focus on the areas where people would stay for a period of time. On the day of the observation the weather was sunny, no clouds and a temperature of approximately 20°C. As result of this and a second hand market on Store Torv, a lot of people were using the town square.

From the observations we found that people often took breaks from their activities to relax on the benches in the sun. They would sit there for about 10-15 minutes, reading a newspaper, a book, looking at their phones or at the people passing by. Some got up and left by themselves, in the group or couple they were sitting in and some left when the ones that they had been waiting for arrived. Another common denominator was that a lot of the people had things with them (e.g. shoppingbags, a pram, bags) that signalled that they were there for other reasons. Lastly it was common that people was eating, smoking cigarettes or drinking coffee - activities related to pleasure and relaxation.

From observing the town square in regards to its physical properties we found that the buildings were covering the wind from two directions. We also found that the sculpture, benches and other permanent installations were placed in one side of the square, leaving room for passaging and non-permanent set-ups on the rest of the square.

Interviews at Store Torv

When people were about to leave the benches on Store Torv we asked to interview them. We carried out four semi-structured interviews, with two adult couples and two individual adults. They were asked why they decided to stay on the town square and what they liked and disliked about Store Torv. Two more individuals were approached, but did not want to be interviewed and appeared offended, probably because they saw the places as somewhat private. From the interviews we found that people often stayed there to wait for their friends or family or to rest in-between a shopping trip or a city vacation.

When asked why they chose the exact location to stay at a Copenhagen couple answered *"because the sun is shining and because we are in Aarhus to enjoy our lives for a single day [...] and because we like to find the places where there is a high amenity"*. An older man also replied *"I am not going to be here for a long time. I'm just waiting for the others"*. From this we know that people use it both for recreational and practical purposes.

To what they liked about the spot the Copenhagen couple answered *"We were happy about the city art, with the water (a fountain) [...]. We like the idea about a nature element in the shape of water flowing and the sensuous feeling of listening to it [...] and the kids playing and using it so it is interactive and becomes a real urban space [...]. And it should defiantly not be covered with a roof."*

The couple had an obvious interest in culture and experiencing. They valued the liveliness and engagement that could be created by the sculptures or other installations in the urban spaces and wanted more of this. They still wanted these not to interfere negatively with the space by shutting it off from the rest.

The response from the old man was a bit different *"For an open space it is too large. If there were a bit more environment [...]. It is not just enough with the sculpture [...] it could be a bit more intimate than now, where it is very big and cold "*

He would have liked there to more than just the sculpture to add to the intimacy of the square. He also later compared it to the town squares in a lot of German cities, where he thought that the use of trees and green areas also added to them.

Generally the answers showed that people liked to sit in the sun and take in the liveliness of the city. The people liked that there was a sculpture but wished for both more culture and nature to make the town square more appealing. Afterwards these findings were summed up to the following design criterias:

- The design should not cover its users views, nor the sun
- It should add to the aesthetic value of the urban space
- It should leave some personal space for the users

Observations at Dokk1

Later in the process an hour of observations were made around the area of Dokk1, a new building for the library and Borgerservice (citizens advice office) in Aarhus. This was done as a concequence to a change in scope meaning only focusing on wind as input, which will be elaborated in the process section. Dokk1 is located right by the harbour front and opened in June 2015. We made observations in early November with a temperature of approximately 10°C. Outside the main building, steps up from sea level a big playground and some benches is located. Just down the stairs the area is big and empty as seen in figure 2. The area is newly created and suited both for adults and children.

From the observations we found that the area had no people around either on the playground or the area at the sea level. This could be explained by the strong wind and high chill factor we felt when walking around the area. We did not feel the wind on the way to Dokk1. We also noted that the area at the water front was wide and open and had no benches, wind cover or anything to make it comfortable.

From the empirical work, we determined that a urban interactive system should facilitate green areas or sculptures and create a more pleasant space to relax, meanwhile letting users observe the urban environment and its inhabitants.

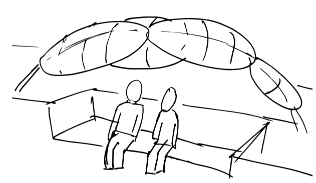
DESIGN PROCESS

In this section the focus will be on the process of our project. We will describe some of our early physical prototypes and sketches on our design, along with the iterations and delimitations that the prototype has gone through up until arriving at the high fidelity prototype.

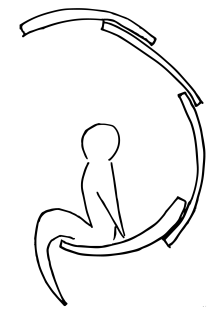
The design process consisted of several phases. The first iterations were made after the observations and interviews on Store Torv, and were designed to satisfy the circumstances that followed this setting. Early iterations were made to support all kinds of weather, but with a changed focus to only cover wind to simplify the problem, the requirements for the prototype were also made simpler.

Protection of a bench

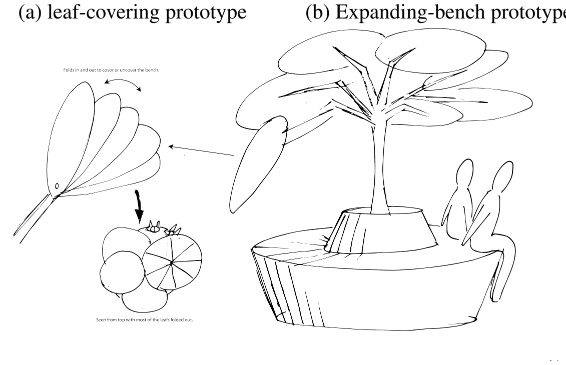
Early low fidelity iterations such as figure 3a and figure 3b were designed to accommodate a bench. The idea behind figure 3a were to create a cover for the rain with its leaves. In sunny weather the cover would transition to a passive state behind the bench. Rain is one of the more static elements of weather, since an interactive system only needs to go between two transitions, protecting from rain or open up to let the sun shine through.



(a) leaf-covering prototype



(b) Expanding-bench prototype



(c) The tree with leaves concept

Figure 3: Early designs

This makes it a less interesting problem for shape-changing interfaces, that excel in being able to display multiple states trough going start to end of its interface[10]. Figure 3b was an expanding bench that was able to cover more or less of the users depending on the weather. The weakness of this concept came from it only being able to make cover from behind, thereby making it vulnerable to wind.

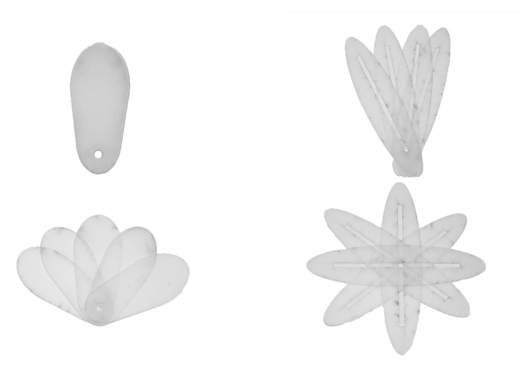
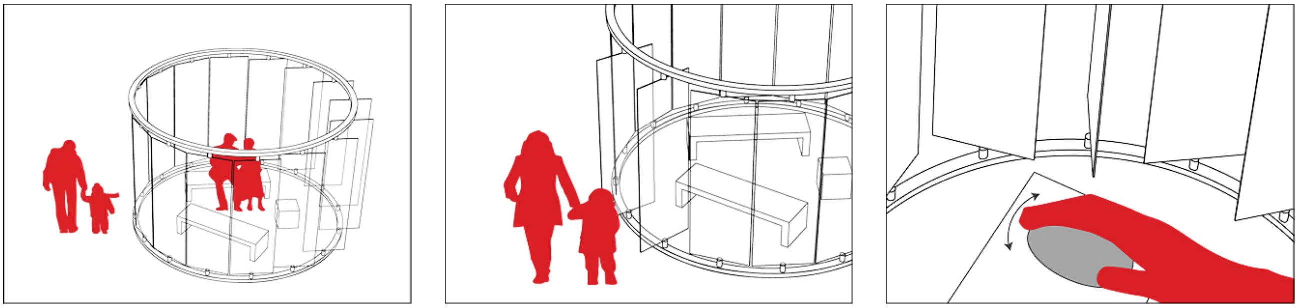


Figure 4: Pictures of low fidelity prototypes on different leaf constructions



(a) The wind interaction with the prototype | (b) Inviting the user inside | (c) The user controlling the prototype

Figure 5: Illustration of the three experiments.

A tree with leaves

One of our early low fidelity designs that we found especially interesting was of the structure analogous to a tree. The supporting objects would be the tree stem and the leaves of this tree would be able to unfold and shape a shelter for rain or wind. The idea of drawing took inspiration from nature, an element interviewees expressed a need for in urban spaces. The tree-like structure could be placed in the middle of a round bench and thus cover a large amount of sitting space. A full sketch can be seen in figure 3c.

We made different designs for the leaves in order to explore what method of unfolding worked best, and to visualise how big an area the leaves would be able to cover. The prototypes of the leaves were made by lasercutting them in plastic and wood. The plastic prototypes can be seen on figure 4. The idea with the leaves was that they should be flexible and fold out in clusters to give them an organic feel thus supporting the concept of a shape-changing interface. The whole construction with stem and cover were designed as asymmetric to be able to cover varying wind directions, which would open the opposite direction for a better view of the surroundings meanwhile covering from the weather.

There was however complications with finding an implementable solution that was not of high complexity in regards to electronics and construction. Every cluster of leaves would require a strong servo to fold out and the stem would need a turning mechanism, to be able to direct its crown towards the wind. As the prototype would have to react in response to all kinds of weather it would also require a lot of different sensors (e.g. wind direction and raindrop sensor modules). All this heavy technology would force a building challenge, since the construction would have to carry it mostly in its crown.

From the experience with this concept we decided on narrowing our scope to simplify the design. Still with focus on shape-changing interfaces we wanted a structure that outputted dynamical movements. Therefore we chose wind as the narrowed problem as it changes dynamically and often through several phases, opposite to rain that is either raining or not.

FINAL CONCEPT AND PROTOTYPE

This section will explain the concept of WindO and how the prototype has been designed both constructionally and technically.

Concept

WindO is a concept aimed at making outdoor urban spaces more usable and enjoyable in windy weather. WindO is a circular construction with transparent acrylic plates that together creates a space within the urban spaces. The rotation of the plates makes it possible to walk inside the construction from one side while the other side covers the wind. The plates should be seen as a collective structure and by that it makes a dynamic change in spatiality as it reacts to its inputs [10].

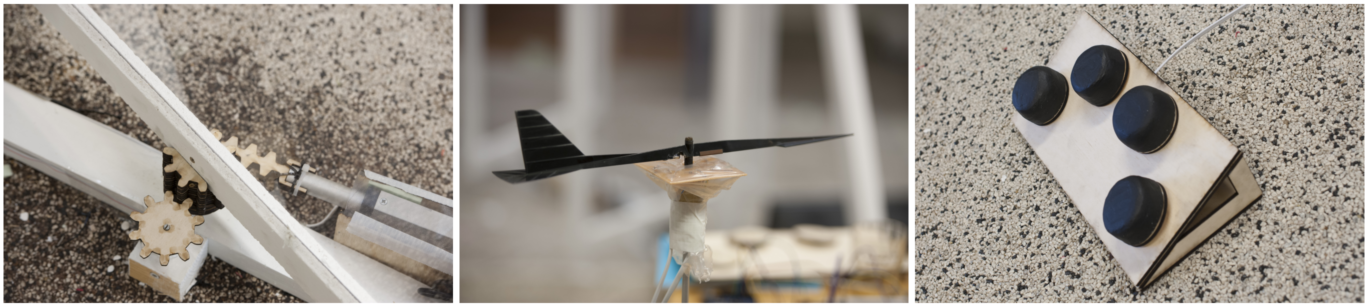
WindO has different possibilities of interaction forms. We will investigate if different interaction types can influence the way the users use the urban space. In windO we investigate three different interaction types as illustrated in figure 5. The first interaction is an indirect interaction, where the rotation of the plates is depending on the wind. The plates covers the wind and is open to walk in from the back as illustrated in figure 5a. In the second interaction the user is indirect interacting with the prototype. When the user walks by WindO, the plates near the user will open up and invite the user inside. This is illustrated in figure 5b. In figure 5c the last interaction is illustrated. Here the user is given direct control over the prototype by rotating the plates through knobs.

Prototype

The prototype of WindO can be seen in figure 7. Due to limited resources the prototype only consists of a part of the concept. The frame of the prototype is build from wooden beams and the plates from wood and acrylic. To make the prototype stable even in wind it has wooden beams to support the structure. Each of the plates are placed in a ball bearing in the bottom and hole in the top beam so they can rotate separately. The prototype has two different kinds of inputs to make the plates rotate; a weather vane and a manual control board. The technical implementation of the prototype will be explained in details below.

Technical implementation

The technical implementation of the prototype can be divided into three different parts; the bottom of each plate that makes



(a) The rotatable part of the plates. (b) Weathervane (c) The manual control board.

Figure 6: The main parts of the prototype

Figure 7: The WindO prototype

it rotate, a weather vane, and a manual control board. All the different parts are connected to an Arduino Mega that is controlling the prototype.

The plates on the prototype is moved and controlled by a linear actuator, gears and a potentiometer. This part is seen on figure 6a. The linear actuator does not output its position, so the potentiometer is used to control where it is currently placed. The gears make it possible to rotate the plates 180 degrees with the linear actuator.

The weather vane on the WindO is seen on figure 6b. It consists of a rotatable part and a set part. The rotatable part is moved by the wind. The set part is a board with eight reed switches that is activated by a magnet placed on the rotatable part so the reed switch in the opposed direction of the wind direction is always activated. The direction of the wind is mapped to eight angles of the plates so each of the plates will be able to cover the wind.

The manual control board has four rotatable knobs on a box as seen on figure 6c. Each of the four knobs rotate a potentiometer. The four knobs are each mapped to a plate such that the plates rotate when the corresponding knob is rotated.

Each of the two inputs that control the plates are changed in the code on the Arduino.

EVALUATION

This section will cover our evaluation of the prototype with three different experiments. We will briefly explain how we evaluated our focus in the given tests, how people behaved accordingly to the type of interaction, and lastly suggestions and thoughts they had in mind.

For the evaluation we had three different types of input for WindO; first we focused on focused on people walking by the prototype meanwhile it opened to them (indirect interaction), second we made the test persons control WindO (direct interaction), and finally we observed wind as input (indirect interaction). Our data was gathered from observations of thirteen individuals with backgrounds ranging from students to full time working people. Ten studied at the university in Aarhus, one at the Business Academy in Aarhus, and two full time workers. The distribution of the people used in the different tests is seen in Table 1.

Category of users	*Indirect(Door)* Lab test	*Direct* Lab test	*Indirect(Wind)* Outdoor test
IT students	7	10	3
Other students	1	1	0
Full time workers	0	0	2

Table 1: Users and tests in evaluation of the prototype

We evaluated WindO over two days where we focused on the desired aspects. We made controlled tests in the lab where we focused on how people reacted upon the indirect interaction when they were nearby and what they felt when they were interacting with WindO directly. For the controlled test in the lab we started off by explaining a relevant scenario for our test persons. We then asked people to start walking and observed how they behaved accordingly to the prototypes reacting to them walking by. They were asked questions upon their reactions. As a foundation for observing how they behaved when they were given direct interaction they were handed the manual control board able to control each individual plate. In the outdoor test we focused on how people behaved when they were left no possibilities for controlling WindO. The weather was almost freezing and not many dared to take a walk outside. Few people chose to pay interest for a short amount of time as a break from their usual routines. The people whom we

Figure 8: In the wind evaluation of the WindO prototype

observed had no knowledge of the concept and purpose of WindO.

Indirect interaction: Using the wind as input

With wind as our source of control we moved our prototype out in the wild and placed it in front of Incuba, an incubator building for Aarhus University and cooperating companies. The prototype was set up and functional before the lunch break so people had the chance to discuss it with their colleagues during the break and walk outside for inspection. That did unfortunately not happen. Only two people approached WindO wondering about its purpose. Given the wind almost did not vary at the day they started to inspect how it worked as seen on figure 8. One of the guys was focused on the gearing with the linear actuator when the wind changed and jumped back as he did not expect it to move.

Some of our test persons from the observations in the lab liked the part that the plates are waving rather than being all open when no one is present inside WindO. They thought it would feel kind of like a trap if they were wide open waiting for a prey. One user mentioned that he would not like others to be in control of how he was to be exposed when spending time in WindO.

Indirect interaction: Inviting people to use the space

Using the Wizard of Oz[1] technique we faked the behaviour of the prototype to make an invitational gesture by opening the plates towards people walking by. All the test persons noticed the prototype opening up when walking by but mostly because of the sound from the rotation of the plates. Peoples reactions ranged from completely stunned to eager to go inside. The majority of people behaved in a controlled manner by inspecting the construction and awaiting it to freeze before stepping inside. One waited for an indication, a permission to enter. Some even chose to take a step back, awaiting their partners reaction and then followed. Others were even more withholding and were almost walking past it before they returned for inspecting its behaviour. They did not know why or what it had reacted upon. Common for most test persons were that they felt the opening as an invitation aimed towards them.

Direct interaction: Letting people interact with WindO

We made a test examining peoples behaviour when they were given the control of WindO. When they interacted directly with WindO they showed a lot of enthusiasm as seen in figure 9. People found it both satisfying and engaging. *"I've got the feeling that I'm in control" ... "It's pretty funny . . . It's actually really nice"* People almost used it as a toy and played around for a good amount of time. *"I can spent all day doing this."* A person made associations to some toys she remembered from her childhood playground where certain rotations made some parts of a larger toy rotate. People were cautious when they were given the control without any further information. First they rotated an arbitrary knob, awaited the response, and then chose another knob and awaited a similar response. They then started to interact with multiple knobs simultaneous for figuring out whether they were limited to one or more knobs at a time. *"I'm feeling like a DJ"*. People quickly understood the spatial mapping between the knobs and how the plates moved. Some uttered they were missing indication for how to interact with the knobs. They wondered if a small rotation accumulated the rotation or it was supposed to be turned all the way to the edge. Some felt a little confused because they were able to rotate the knobs faster than the plates were able to follow. One suggested to have a button which only had to function as a full cover that would align all plates in a perfect circle for blocking all possibilities for entrance/exit.

User concerns regarding direct interaction

Besides their enthusiasm users stated various concerns raised when they were interacting directly with the prototype.

- Some users expressed they would not feel comfortable having direct interaction with the prototype if they were by themselves and strangers walked by. Another person added he would turn to another direction of the installation, if he were to continue interacting with WindO.
- Our test persons would feel a higher degree of freedom for interaction if they were accompanied by friends or relatives independent on they were seated at the bench or playing around nearby. They would welcome people inside if they knew them in advance by opening the plates. Some feared they would not feel comfortable by just enjoying a relaxing moment if the purpose solely was to play with the interaction.
- They would feel engaged playing around for some time and then feel the urge to leave and thereby giving the opportunity to strangers passing by.
- By gaining full control some felt they lost the part about being uncertain about why WindO was moving between different stages.

Figure 9: Users interacting directly with the prototype

General thoughts about WindO
Almost every test person felt the opening behaviour as some kind of invitation. People found it to have a functional purpose. Some felt they were being protected behind the plates. They liked the part that it was possible to enter through multiple spaces rather than a small amount of fixed locations. People liked the speed the linear actuators provided for rotations. Some imagined they would feel the complete installation more appealing as a space for wandering compared to our quarter section prototype. They imagined it would feel like an open space. Some would have liked to experience of the full prototype for a better understanding of the case.

Depending on the source of control the test persons were afraid they would end up trapped in WindO. A person suggested to have a designated door for clearly stating where to enter/exit at any given point. She were then given direct interaction and did not feel the urge anymore.

Almost everyone felt they were a part of an exhibition by being inside WindO if they were behind a window. *"I feel like I'm a gorilla in a cage."* Not all made the analogy to an animal in a cage but just did not want to feel like they were reaching for attention. Some wondered about whether relatives or friends would like to use WindO as a shelter by entering with this in mind. They suggested that we should expand the sheltered area to multiple benches rather than multiple shelters for individual benches. They compared it to being at the zoo and looking at individual animals separated by breed. Some suggested to use glass with varying colours in the complete installation. *"It would be like a kind of an excuse for sitting and enjoying the view when the glass had different colours"* People pointed out that they would be more curious if they did not know what was hidden behind the shelter but would miss out on the view which was more important to them. If people only were able to look out they would find it thrilling but creepy at the same time. A lot of our test persons would like to spend time with our prototype if it were to appear in Aarhus (e.g. Store Torv, Dokk1, as a replacement for urban spaces static shelters). One even suggested he would like to have it in his backyard if it was build properly.

Summary of results
The tests revealed many findings that we found useful. The following list the most important points:

- The test persons were often surprised by indirect interaction
- Users understood the invitational gesture but the responses to the gestures were mixed
- People felt uncomfortable when they did not comprehend, where the input came from.
- Direct interactions was enjoyable to the users and made them more willing to use the prototype
- The cage-like shape made many test persons feel exposed

DISCUSSION
This section will be a discussion on the project. First it will focus on how the tests were carried out and the sources of errors along with other influences on the data. A discussion on the results will follow with an elaboration of our findings. Finally there will be a subsection about future work with relation to the subject of our project.

Results of evaluation
One of the important findings from our evaluations was that many people were taken by surprise when the construction started moving even though the gears were visible to them. Several people even made a leap backwards from the prototype. This was clear in the uncontrolled test, where one of the persons was examining the gears when it started turning and backed off in a hurry. A note to this scenario was that the interaction was actually indirect, because the test person did not get the coupling between the wind direction and the output because it had not been moving yet. This was a feature of the prototype that conceptually would be removed by a way higher resolution of movement and wind direction sensoring. Some users hesitated entering the construction when it opened because they found it unpredictable. They did not recognise it as indirect interaction, and considered it to be no interaction. As seen in Rasmussen et al.[10], no interaction can have a frightening effect on the users and keep them from using it.

We also believe that the scale has an important saying in this effect on the users. A parallel can be drawn to Gronvall et al's coMotion Bench[5] where some users become uncomfortable when the bench that they sat on changed shape for no obvious reason to the users.

The reactions were different when the users could directly interact with the prototype. Even in the cases where it was other users who had the manual control people were more eager to enter and move around between the plates. The users would coordinate with each other about what to do with the construction and they became more playful. This could once again point to that users are more comfortable with using shape-changing interfaces if the the output is a response to a tangible and direct interaction.

One of the tendentious responses from the test persons during the controlled test was that they felt exposed when surrounded by transparent plates. With the knowledge from the observations and interviews at Store Torv, this had almost the opposite effect of the intended, since people wanted privacy while observing others.

Shape-change and the prototype

Our vision was to create a shape-changing shelter which covered wind coming from arbitrary directions. We sought to create shape-change with Rasmussen et al's spatiality perspective in mind. As each plate is acting individually they are able to break free from the composite structure. We succeeded in fulfilling this. The linear actuators in the prototype were though making a lot of noise when changing between stages and the transition was never fluent resulting in the transitions appearing mechanical. People were often scared when our prototype would start to move, though they did not have similar emotional responses to the interfaces as seen in *Living interfaces: the thrifty faucet* [12]. The major difference was that the transitions in Thrifty Faucet were associated with Anthropomorphic or Zoomorphic movements as described in Rasmussen et al. [10] while ours was mechanical. We would like to reduce this level of noise and non-fluid transitions for future iterations to make the experience more pleasant and emotional engaging.

As seen in the figure 1 of our concept we would like to cover the mechanical parts of the construction. The prototype would be a circular installation where the mechanics that make WindO shape change would be hidden from view. We hope this would make the experience more pleasant in two ways; moving the mechanics to the background of the users attention, and secondly mitigating the noise caused by the mechanical parts. We see potential in a motor creating more fluid motions, to make the prototype seem more organic.

Causing commotion[5] highlights three aspects when designing shape-changing installations in the wild; affordance of shape-changing interfaces, transitions between foreground and background, and interpreting physically dynamic objects.

The static affordance of WindO regards sheltering for the wind, as almost every test persons thought was the intention. The dynamic affordances would be perceived with more ease if the granularity of the weather vane were finer causing the plates to alter their positions more frequent and make it seem more smooth rather than mechanical. Jung[7] points out, that if we do not want to surprise the user we have to provide cues (e.g. structural appearance). For both cases covering indirect interaction we did so by making the plates open towards the transient users or letting the wind control which way the plates should face and when they were to rotate. Under both circumstances the users approached a static shelter which suddenly started to rotate and caused them to pay attention. They missed indications that the prototype would rotate. This behaviour was similar to the reactions caused by coMotion[5].

In contrast to coMotion which transits from background to the foreground of the users conscience, WindO is aiming for moving in the other direction. We would like to make people aware of WindO and the possibilities it provides and then fade to the background of peoples conscience for facilitating companionship or simply a break from everyday life. In our test, the users were focused all the time on the actuators and windows. This was very obvious in the two tests with indirect interaction, where the users had no control. They kept attention to the windows every time they moved. This changed clearly when they gained control over the prototype. It stayed in the foreground meanwhile interacting, but more in a situation where the users expected output through their interaction. It slipped into the background, when paused or finished with playing with the prototype and had started communicating with other test-persons.

Regarding how our test persons interpreted the physically dynamic objects they had an idea about the purpose of the transparent plates in front of them contrary to the case for coMotion[5]. All but one of our test person reflected upon the opening gesture and entered after a varying amount of time which was our intend. They figured out it was supposed to act as a shelter regarding the wind. In general they liked the pace in which the plates rotated.

Implementational Challenges

The construction and implementation of the prototype had a few challenges on the way. Since the prototype should be able to stand outside in urban spaces it is required that the construction is very strong and solid [2]. This was hard to conduct without it taking a lot of space due to the size of the prototype. Also the control of the linear actuators with the potentiometers has been a challenge. A minor error in the rotation of the potentiometer makes the whole plate rotate in the wrong way or not rotate at all. When the prototype needs to be moved the potentiometers and linear actuators needs to be calibrated so the rotation will be correct.

Limitations of the evaluation

The first evaluation were carried out was made indoor in a controlled environment since it was not an optimal day for outdoor evaluation. This meant that we had to find test persons, who ended up being mainly computer science students. The test persons therefore already had a certain point of view with their education and knowledge that other test persons would not have. The research results has been restricted by few and a narrow range of participants in the evaluation.

During the outdoor evaluation the prototype was left alone in the hope that the prototype would grab peoples attention and make them interact with it. This was unfortunately only the case for few persons. This might be due to the fact that the day of the outdoor evaluation was very cold, a day where most people just wanted to get inside. The location was at Katrinebjerg in Aarhus which mainly consists of educational buildings, companies and residential buildings. If the prototype was set on Dokk1 or at some place where people would go for experiences, more people probably would try the prototype. A full scale of the prototype would finally have seemed more finished, and people might not have thought that our prototype was all set-up and ready to interact with.

Future work

One of the things we would like to examine should concentrate about trying to understand what causes users to get frightened when exposed to shape change under certain circumstances. We would like to explore if people feel more comfortable if an explicit indication for entrance and exit were present in our concept. Possible experiments could be signifiers. Is it solely because people do not expect the change in shape or are multiple factors the cause? As seen in earlier studies shape-change is capable of causing commotion[5] when users do not expect the properties of shape change. On the other hand users seem to actually enjoy the present possibilities as seen in SpeakCup[14]. Is it caused solely by expectations or does the size of the product have something to do as well?

The prototype had a rough granularity which made the transactions between stages harsh which might have had a deep impact on people. By gaining a finer granularity the needed degrees for a change in direction would decrease. When less is required for it to rotate the chance for it to rotate when people are walking towards it are higher and thereby making them aware that something is causing the plates to seem lively. This would then indicate to the user that this may not be as static as assumed if people made a brief glance. The acceleration of the movement could also be interesting to look at it, since a slow start could warn the user that the object was starting to move.

We observed that people correctly acknowledged the opening gesture as an invitation for entering the sheltered space but were withholding to follow through. People were afraid they would get trapped inside it. It would be exciting to explore which necessities needs to be made to make people feel comfortable with following the invitation without being reluctant.

The users felt a loss of privacy by entering our prototype. In further work we will explore how we with installations for the user can create a private space in an urban space. A space where user feel comfortable and hidden from transient people, meanwhile keeping the urban space communal.

CONCLUSION

In this paper we have presented WindO, a body scale shape-changing interface to explore the potential of shape-change to extend the use of outdoor urban spaces. By making two different test with three different experiments we were able to conclude that people behave in different manners whether they were in control or not. Through the indirect interaction the users got frightened by the transformation of the prototype. It took them several seconds to comprehend the shape-change. We expected the users were able to connect the shape change with the wind direction or their proximity to the prototype. We concluded that participants felt safe when they were interacting directly with WindO or detected another person was controlling the prototype. After entering WindO people felt they were exhibited for transient people, an unpleasant feeling to the users.

The prototype seemed mechanical to the participants, this we expect to be caused by the granularity of wind being in control. The rotations appeared rough while moving, and the wind were able to obviously change direction, without making the prototype move. We believe these two important factors were responsible for frightening people. It was the sudden rotations that caused the test persons to get frightened, acceleration could be one solution to ease the transformations. To improve upon the transformation, the granularity is required to be more subtle, this would make WindO more dynamic and thereby alerting people of the shape-changing aspect without frightening them. Depending on the types of interaction they had different expectations to the prototype. Through direct interaction they felt in control of WindO and they expected it to react according to their demands. With indirect interaction they did not know what to expect as output, and they were therefore cautious when they approached WindO. Lastly every test person had the assumption, that the purpose of WindO was as a shelter for wind, controlled by wind or through direct interaction. They were able to recognise its potential and saw its use in a real-world setting.

In future work we wish to examine what causes the users to get frighten when using shape-changing interfaces. Whether that be users not understanding the properties of the objects, the size of the interface or the granularity and speed of the transformations.

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