SoleMate

Designing for copresence using connected soles

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Abstract

SoleMate is an explorative design project striving to achieve the ambient feeling of copresence between people without the need of physical presence. Two pairs of shoe soles are equipped with pressure sensors and vibration motors and are connected through the internet. A step taken with one pair of the soles results in haptic feedback in the other, and vice versa. We provide a walkthrough of the iterative design process as well as insights and considerations on the design choices leading up to the final prototype. The results of user testing indicates that walking with SoleMate on a distance provides the feeling of copresence and could therefore reduce the feeling of loneliness while walking alone.

Introduction

In a time where the practice of social distancing has a substantial impact on a society's health, finding new ways to socialize without sharing physical space is important. Simple interactions such as taking a walk together is something that is difficult to do while being apart.

The term copresence is used to describe how we, and our actions, are affected by the presence of others. Copresence, and the creation thereof, is a quite heavily researched field when it comes to for example VR or communication applications and interfaces. What we aim for with this project however, is to create a copresence of a more abstract nature, one that is present in the back of your mind rather than being the focus of your attention. SoleMate is developed with the aim of connecting people beyond the boundaries of physical presence and to create an immersive experience of copresence without requiring direct action or feeling intrusive. Through a system of connected soles, SoleMate lets two people experience each other's footsteps as haptic feedback when walking. Each sole is equipped with a pressure sensor beneath the heel and a small vibration motor on the side of the foot which are both connected to a microcomputer that wirelessly transmit walking patterns over the internet. A step taken with one person's foot will trigger an impulse of haptic feedback in the other's corresponding shoe and vice versa. Due to our inability to communicate intricately using only footsteps, the use of this technology provides a passive companion, a reminder that you are not alone. In combination with other communication however, we believe that this technology can enhance the perception of copresence greatly. Talking on the phone while simultaneously walking or jogging with the haptic feedback of the other person's footsteps may create a feeling of togetherness and a sense of being present in the same space.

Related work

Copresence and telepresence

Copresence, a term coined by Erving Goffman in 1966 [4], was used to describe how individual action is influenced by the presence of others. More recent interpretations of the term, however, state that the physical presence of others is not needed to create copresence, neither is it sufficient. Just because two people are physically present in the same room doesn’t mean that they will achieve copresence. On the other hand, one may create and occupy shared spaces using media-technological tools and services while not being physically present. Campos-Castillo and Hitlin bring additional views on the term[1], meaning that copresence should be viewed as a perception, and is therefore something highly intraindividual. Furthermore they emphasize that it is not an “on or off”-phenomena but something that we are able to slide in and out of in varying degrees as our attention to stimuli varies. This is how SoleMate is intended to work as user’s should be able to, and is even encouraged to, let the input from the haptic feedback float to the back of the mind and concentrate on other things, providing more of a passive copresence.

Other components prevalent in copresence are mutual attention and mutual behaviour. The way SoleMate is designed means that the focus of one actor is, at least passively, on the other actor and vice versa, providing mutual attention. This should not be mistaken for joint attention where the two actors’ focus would be placed on a third object such as the interface itself[7]. In the design process, this was taken into consideration to make it as non-intrusive as possible. Mutual behaviour concerns one actor’s conscious or unconscious mimicry of another[6]. A point of interest in the development of SoleMate was to understand whether this haptic feedback would trigger mimicry in users. The way we imagined it working was that users would initially focus on the rhythm of each other's footsteps, and would then gradually let it slide to the back of their minds, becoming unconscious mimicry.

Another term frequently talked about is telepresence, the notion of being present in a location other than that of your physical location[2]. When telepresence is achieved, the interface used to communicate or to do work is set in the background while the actual communicating or task at hand is moved to the foreground. For two people to experience a shared presence in a physical space not inhabited by the both of them would in some sense mean a combination of both of these terms, copresence and telepresence.

Soma Design

Designing for interactivity between technology and parts of the body, in this case feet, can be approached using different techniques. Soma Design is a concept that utilises the body and movement as the main driving design force, as opposed to the more traditional use of language and rational[5]. Using Soma Design, Windlin et al has developed six different physical shapes, to be placed on the body and interacted with, called Soma Bits[8]. The Soma Bits can emit heat, vibrate and change shape and are built as a tool to help designers become aware of how a design might feel like. They are not considered a “finished product” but more of a framework to be built upon by others. This is also a possible take on SoleMate, as the project is of exploratory nature and could easily be improved and added upon by other designers in the future. The concept of Soma Design was also applied to some parts of the design process as it felt fitting when working on a product simulating a bodily action.

Nebula

Wearable technology, a term used and further explored in [3] where textiles and digital technology is combined to create interactive garments. This paper explores how to design these garments in terms of materials and equipment. The discussions and design decisions regarding the materials of the Nebula inspired the design process of SoleMates physical prototype. From the final reflections of the study Elblaus et. al states:

“Interactive fashion should be designed by considering the properties of interactive technologies and textiles in tandem”

Which also was taken in consideration to be able to clearly receive the input of pressure and deliver the output of vibrations without making the clothing items uncomfortable to wear and overwhelmed by digital components. Further, a goal was also to make the technology as invisible as possible to let the users focus on the experience of using SoleMate and feeling their friend's presence. Therefore, SoleMate also uses wireless technology, similarly to the Nebula, such as the Arduino Nano with wifi capabilities to avoid restricting movements when used.

Methods

Brainstorming and exploring the design space

During brainstorming and exploration of the design space we talked about different modalities acting as input and output and what could be considered their strengths and weaknesses. We decided on excluding the modality of sound because of the common use of music, podcasts and phone calls during walks on your own. With the goal being copresence, talking to your walking partner is already contributing to that goal. We therefore decided to strive for a design that could work as a complementary modality as well as a stand alone solution. We decided to continue to explore haptic feedback in the shape of small vibrations as a possible output modality because of its potential of unobtrusive and subtile presence.

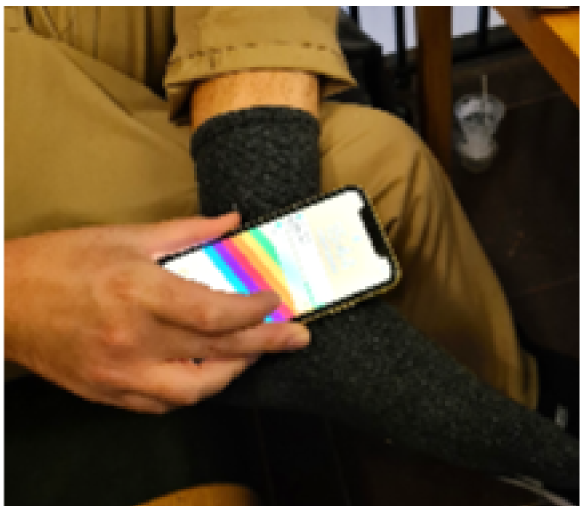
Walking sessions

Photos from the walking session

A first person evaluation of walking patterns was made in the early stages of the design process with the goal to gain insight in how we relate to tempo and to each other while walking. To our aid we had smartphone metronome applications providing audio signals as well as an Apple Watch able to provide haptic feedback in a set tempo. All experiments were made in both 90 and 110 BPM to gain an understanding of whether results change at different tempi. To record opinions and insights, a short survey was conducted after the session. The session consisted of different scenarios and all four authors experienced and reflected on:

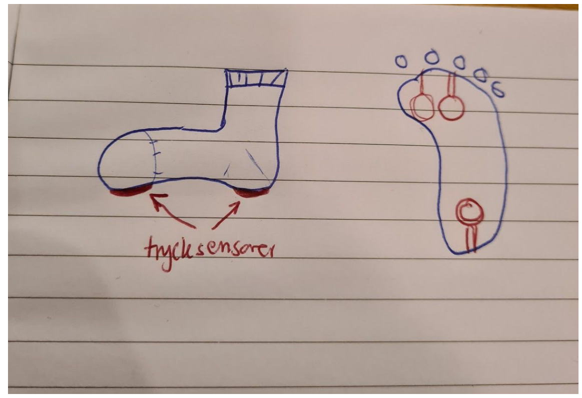
- Walking alone with/without metronome
- Walking in pairs with/without metronome
- Closing one's eyes while walking to a metronome

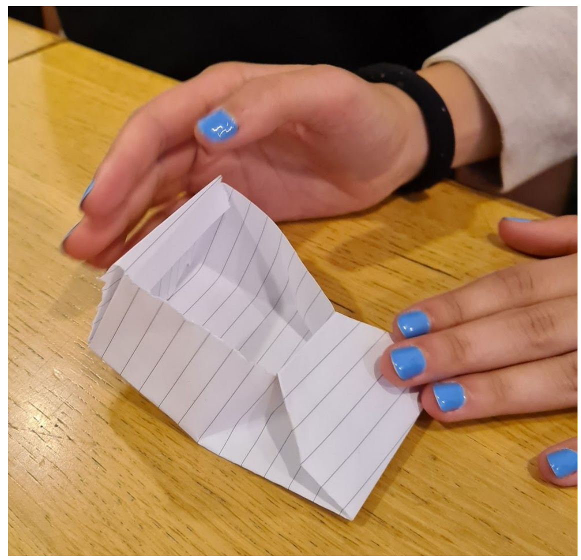
Insights from the session were many, among others it was found that all participants found it quite easy to walk in sync with a metronome, both using audio and haptic feedback. Regarding the haptic feedback, one interesting thing that became apparent was that walking in sync with the tempo while tucking the Apple watch in your shoe at the top of the foot rendered the feedback almost "invisible" while off-sync steps felt more pronounced. Of course, this is highly dependent on the intensity of the feedback but it also opened our eyes to that this might be something that we want to strive for, as it would mean that out of sync steps would feel like they gained a more powerful feedback, effectively helping people into tempo. This exercise was of great help in identifying what we wanted to design as well as potential challenges and problems, but also *why* we wanted to do it. The initial idea, before the walking session, was to build something that enabled people to fall into tempo with each other. An aspect that became apparent after the session was that following the same pace might not be required to feel copresence. Essentially, that just feeling another person's footsteps is far more important than syncing up in tempo when it comes to feeling the copresence of another person. This insight tipped the scale in the decision to go for an internet-connected design rather than a "lower-fi"-prototype using radio transmitters. Even though the former approach would be subject to latency issues making it harder to share tempo with each other.



Experiments with haptic feedback from smartphones and Apple Watch.

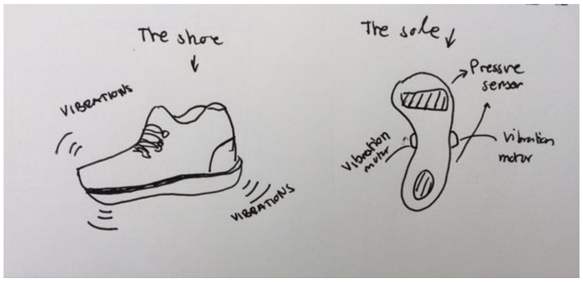
Designs, Sketches & Prototypes





Early sketches.

The design work in this project was of an iterative nature meaning that prototyping, and the evaluation of said prototypes, was an integral part of the design process. The process generally started with sketching and or other forms of paper prototypes, followed by first person testing/evaluation of essential features. If the design or idea proved feasible, it would lead to a more high fidelity prototype.



Concept sketches of different approaches.

Early prototype, testing the sensitivity of a pressure sensor using a led light.

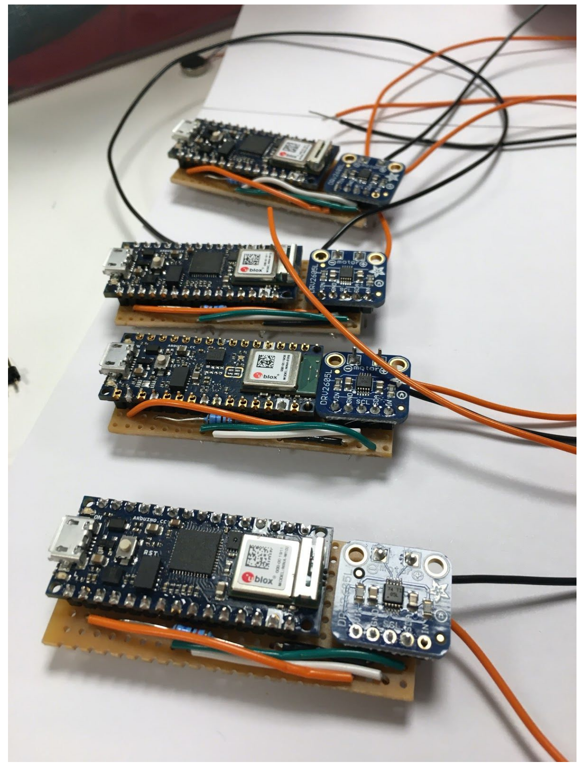
In early prototypes and concept sketches of the design we focused on modifying a shoe or a sole to house all the sensors and equipment. The shoe design was abandoned quite early because of the problem of only being able to be worn by people of that particular shoe size. Reasons to go with a sole design were many however, the sole itself would provide a stable base to fit the sensors as well as being able to place in any shoe of roughly the same size. With this design it would also be possible to place the pressure sensor on the sole's underside making it less susceptible to wear and tear from the foot when walking. When it comes to the placement of the vibration motors, the sole design is however not optimal. From our experiments walking with haptic feedback we gathered that the best placement of the vibration motors would be on the side of the foot, in the arch area, as well as the top of the foot, i.e. under the shoe laces. This fact provides a negative aspect of the sole-design as it requires that the vibration motors would have to be placed under the sole or be fitted after putting the shoe on.

Sock prototype without the pressure sensor and vibration motor.

Sock prototype during use.

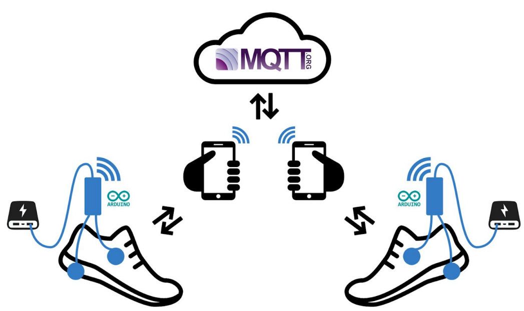
After several iterations, the decision was made to try a sock-design instead of shoes or soles. This approach affords more or less free placement of vibration motors as well as being able to be used by people in a much larger range of shoe sizes than the other designs. It does not, however, come without its challenges. The elasticity of a sock makes it highly fragile in terms of cable breakage or displacement of sensors and motors. Efforts to mitigate this were made in terms of using extra long cables for the sensors and motors and hiding these by sewing cable tracts onto the sock. Another negative aspect of a sock design is the fact that it is prone to get sweaty, one would therefore have to design to make the electronics removable to be able to wash it. One thing that became apparent when evaluating this design was that every foot is unique. This manifested itself in that the pressure sensor, placed on the heel-part of the sock, had a tendency to move around when worn by different people. Although this problem was somewhat mitigated by sewing a velcro patch on the heel, making it possible to move the pressure sensor to fit the wearer, it also made the sock less comfortable to wear.

Technical hardware and software



The four Arduino boards used (Nano 33 IoT), each with a Adafruit DRV2605L haptic motor controller connected to it.

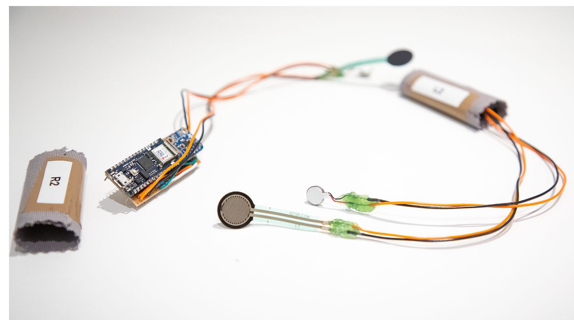
Being a wearable product, SoleMate needed to be powered by a light and small micro-controller with the ability to connect wirelessly with another controller of the same sort. The Bela board was considered as it offers very low latency, but it was discarded because we did not need to process sound (the Bela's main focus) and the latency would mostly be due to how the boards are connected. The choice eventually fell on the Arduino Nano 33 IoT from Adafruit, given its small size and built in wifi capabilities. Paired with a pressure sensor, a vibration motor and a Adafruit DRV2605L haptic motor controller, this was everything needed in terms of hardware. The haptic motor controller made it possible to more precisely control the vibration pattern, giving us a chance to form the output as desired.



Schema of the connection between two boards

Connecting the boards wirelessly proved to be somewhat of a struggle. After deciding to use Wifi instead of radio signals to get better range, we first tried to connect the boards through a database hosted on Firebase. This was unsuccessful but we were then introduced to the protocol MQTT (Thank you Arjun Menon) making us abandon the idea of using Firebase. Being lightweight and Internet of things focused, MQTT was the perfect fit for sending data between our boards over the internet. When a step is taken, the board on that foot simply publishes data to a specific topic hosted by a broker. The corresponding board then subscribes to that topic, having the data pushed to it as soon as it is published. This simple model makes for a really fast and reliable flow of data as long as the boards have a decent internet connection. In the current version of SoleMate the internet connection is provided by sharing it from the users smartphone but future versions could have their own sim card, making it a completely stand alone product.

Evaluation



The working prototype used during testing

After the technical difficulties were solved, such as calibrating the sensors and connecting the Arduinos over the internet, the working prototype was tested in a real life setting. This was done by having two people put on the prototype and then take a walk at opposite sides of Stockholm. To explore how subtle, or intrusive, the haptic presence of the other person was experienced and if SoleMate deepend the sense of co-presence, the walking session was divided into two parts. First the participants had no contact with each other (except through vibrations) and then another layer of communication was added by having the walkers talk to each other on the phone. Comparing the two scenarios, the haptic feedback was experienced as more passive and “in the background” while talking on the phone. This is probably an effect of the shift in focus from simply walking and feeling the vibrations to being forced to communicate verbally. However, the input from SoleMate was not completely overpowered by the conversation. Instead the main focus sometimes shifted back to the vibrations, distracting from the conversation at first, but after a while the two seemed to be cognitively present at the same time, having the vibrations inforce the sense of copresence.

On a more general plane, regardless of scenario, SoleMate proved to send more information and data about the other person than expected. Even if the vibration pattern is the same for every step taken and the only variable is the walking tempo, that was enough to get a sense of several different aspects of the other person's walking pattern and even emotions. For example, a fast tempo could indicate stress while a slower tempo is associated with a more relaxed state. This is of course relative to the person receiving the signal as they compare the tempo to their own and thus a tempo that may feel stressful for one person might feel calm for another. Another interesting finding is that even the surroundings could be estimated. When walking in nature there are far less complete stops compared to walking in an urban setting, where events like crossing roads demands one to stand still. This estimation is of course a bit of a stretch of the imagination without any other input, but combined with the background noise given through the phone call, the type of surrounding could more easily be pinpointed.

Concerning the fit, comfort and visibility of SoleMate, no major issues were apparent during the testing. As SoleMate is meant to be used during longer walks, a non-intrusive fit and maximum comfort is of most importance. The thin pressure sensors placed under the heel were not at all noticeable and the vibration motors, placed on the side of each foot, could only be felt while vibrating. If the motors touched the shoe, the shoe itself acted as an amplifier for the vibrations, making the user feel as if the shoe itself vibrated and not only the small motor. This was important as concerns regarding how one small motor could be too subtle of an output had been raised. The only uncomfortable part was the Arduino strapped to the leg, giving the insight that a comfortable case was needed.

Final Design

The final design of SoleMate

The final design during use

Given the insights of the evaluation and helpful feedback from peers, the final design was changed from the sock model back to the previous concept of more of a half length sole. This change not only made the SoleMate work with varying feet sizes better, because the sensor at the heel always aligns correctly, it also made the hardware less prone to break when taking it on and off, compared to the more fragile sock prototype. The shape, being narrower at the heel and a bit wider on the other end, made it possible to place the vibration motor at the edge of the wide part making it curve up at the side of the foot and not be stepped on. The sole was forged out of silicone, with the sensor and motor placed inside, and wrapped in a thin fabric to maximize comfort while keeping the sticky silicon from becoming dirty. The Arduinos' enclosure was also updated with a new fabric along with an elastic band attached to it, making it easy and more comfortable to wear around your ankle.

Discussion

With the intent of exploring and adding to the research field of copresence, the concept SoleMate was designed and developed. The word ”concept” is used since we wish SoleMate to be seen less as a finished product and more as a base for others to build upon. Our focus has been on connecting people through haptic feedback during the activity of walking, but the technology behind SoleMate could be further developed and applied to many different scenarios. One could imagine something like helping pupils learn what keys to press when learning how to play the piano by simply feeling, through haptic feedback, where the teacher is pressing down. Another example could be helping people that work in noisy environments to communicate with each other.

One of the key points of interest in the development of SoleMate was the mutual behaviour aspect - how users would relate to the entrainment of each other’s footsteps. Our hypothesis was that users would start off thinking about the tempo of the other user and consciously try to mimic it. This also poses interesting questions about how the entrainment would occur, who would “take the lead” and so forth. When people got more used to the device and the haptic feedback we theorised that the mimicry would cross over to be unconscious, similar to the one that often occurs when walking physically next to someone. Our very limited user testing provides indications that this might be the case, the sensation of the feedback “floating to the back of your mind” was prevalent when testing the prototype. However, the inherent latency of sending data over the internet prevents us from investigating the entrainment of tempo further. Even though the impulses of one’s footsteps did reach the other party, it did so with a rather irregular latency - a fact that makes it impossible to draw any conclusions about entrainment. A different design, utilizing radio transmitters instead of the MQTT internet protocol, would probably have almost eliminated the latency issue making it possible to explore these aspects. This would however render the device unusable over large distances as these transmitters are limited by a range of a few kilometers.

Even though it is hard to draw conclusions about the entrainment, the perception of copresence may still be analysed. Although user testing was limited to first party evaluations, all our explorations with the prototypes did render some sense of copresence in the users. One interesting aspect is that, contrary to our initial thoughts, walking in sync with each other was not required to achieve copresence. This fact became apparent during our walking sessions and further cemented while evaluating prototypes in different stages of the design process.

In the scope of this project there was not time for expansive user testing. This would however be an interesting study to make as indications point to that the perception of copresence is prevalent but there are still many unanswered questions. Among them being, how different designs would affect this perception?, if surrounding or setting would have an influence? or to compare physical presence with the copresence generated by SoleMate. The choice to present SoleMate as a concept rather than a product was made to promote exactly this, further exploration.

Sustainability

We believe that SoleMate could contribute to knowledge on the journey towards the United Nations Sustainability Goals (SDG) 3: Good health and well-being[9] and 9: Industry, Innovation and infrastructure[10].

The United Nations Development Programme website states in their description of the goal of Good health and well-being that "Good health is essential to sustainable development". Even though their main focus seems to be on physical health we believe that this also includes mental health. Some say that implementing social distancing in longer periods of time could have a negative effect on our mental health, and now in the year 2020 with the situation of the COVID-19 pandemic, this will be involuntary put to the test on a global scale.

The 9th SDG touches upon the problems arising with the globally trending urbanisation. SoleMate might give some insights to technical solutions that could make urbanisation less of a necessity in a modern society. The year 2020 has proven more than ever that working from home is a feasible option for a lot of modern work tasks. However, the lack of social interaction might be problematic in the long run. We therefore think that it is important to continue the research of technology and design that fills the void of physically present social interaction with equally qualitative social interactions on a distance, and that SoleMate fits that description.

Division of labour

The division of labor has been equally divided throughout the project. The limited amount of group members provided an opportunity for all members to be involved in all parts of the project. So we usually worked on it at the same time. There were of course times when one or two members couldn't participate but the desire to learn all aspects of the project and different schedules has then contributed to situations where one person begins a task and another one completes it.

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Appendix - Pictures of the process