Textile shape-changing interfaces to communicate and design machine transitions.

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ABSTRACT

Shape-changing interfaces present the opportunity to communicate with end-users. Within the context of semi-autonomous vehicles we explore if shape-changing interfaces can communicate the transition from autonomous to manual driving and vice versa. And if taxonomies, which describe shape-changing qualities, could potentially be used as input to design these interfaces. We have described explorations of different textile shape-changing interfaces through co-creation session that are then classified into different taxonomies. The study discusses the meaning of the most relevant taxonomies, which are zero-crossing and texture, also how machine transitions can be shown best and the need for notifications to express different degrees of urgency in hand- and takeovers.

KEYWORDS

Shape-changing Interfaces; Affective Computing; Actuated

Interfaces.

INTRODUCTION

Shape-changing interfaces are physically-dynamic interfaces that can be computationally controlled [1]. Its physical change can be used as an output to convey information [2]. While it is gaining importance in human computer interaction and many researchers are exploring its potential, when these types of interfaces are best, and how to apply them is still unclear. Ways in which the application of these interfaces are specifically explored is for example Ripple Thermostat [3], an interface that uses shape change to explore if through the interaction with a thermostat, affective meaning can be conveyed, the Inflatable Mouse that communicates through the expansion of its volume [4] and Wrigglo [5] which is a shape-changing smartphone peripheral that is able to show the connected user's presence.

Because of its communicative potential we see an opportunity for textile shape-changing interfaces to be able to communicate the transition of changing behavior of machines, and that these interfaces could use shape-changing descriptive features as input to the design process. We explore this within the context of autonomous vehicles, specifically communicating the transition from autonomous to manual driving. We then chose a textile shape-change because this material is already widely integrated within car interiors.

This research aims to contribute a specific way to use descriptive shape-changing criteria, taxonomies, as input rather than as a classification tool. Secondly, we aim to discuss the potential of shape-changing interfaces to communicate transitions in machine behavior. To fulfill this aim we uncover if there are certain taxonomies more relevant than others, we explore this specifically in the context of takeovers and handovers in semi-autonomous vehicles by means of shape-changing textile interfaces in the car interior. At the same time we look at the communicative potential of shape-changing interfaces. Trough co-creation sessions with fourteen designers, various shape-changes were generated. These outcomes capable of communicating the transition were analyzed and categorized based on the type of dynamic change. We end this paper with a discussion about the most relevant taxonomies and the communicative potential of shape-changing interfaces.

RELATED WORK

Communication in shape-changing interfaces

A domain in which the expressive qualities of shape changing interfaces have been explored is, among others, mobile phones. Wrigglo [5] uses the expressive qualities of shape changing interfaces to communicate the behaviour of someone that one is talking to but cannot see. Similarly, Dimitriadis et al. [6] investigate the effectiveness of in-pocket notifications in the form of shape-changes. Both focus more specifically on the kinetic aspect of shape-changing interfaces, while we believe that the aesthetical aspect in our context can play a big role in the end-user understanding of the transition.

Amanda Parks et al. state how through physical movement we can recognize and express certain basic emotions [7]. These different expressive qualities are also explored by Haodan Tan et al. by proposing different shape-changes and asking different participants to identify six basic emotions emotions [8] Similarly, Stroheimer explores similar concepts only focussing of 2D flexible surfaces [9]. These different studies substantiate that shape-change can inform and convey information and has the potential to affect people emotionally. Focusing on the automotive sector, we see an opportunity for shape-changing interfaces to communicate the intentions of automated vehicles.

Taxonomies

There are researchers looking into the potential and developing toolkits that would serve to create shape-changing interfaces more easily [10][11][12]. Instead of developing a new toolkit we want to propose an existing classification tool to be used as input material to a design process instead. The tool we want to propose specifically are taxonomies.

Taxonomies are classification criteria for changing shapes, such as volume, material qualities and texture. The taxonomies used in this paper are based on the analyses, strengthened and unified version of the Morphees + research paper [13]. Though these taxonomies originated from the shape resolution criteria of Roudat [14] and the deformation types defined by Rasmoussens [12]. For clarification, the taxonomies used in this paper are described below:

Area, which is change in the surface of the object.
Curvature. The curviness of the surface.
Zero Crossing is the change in the angles and direction of different points on a surface (for example waves).
Closure, the closeness of the shape taking the edges of the area as reference points.
Amplitude, which we can consider the change in distance between the actuated and the rest position.
Strength, which is the force needed to move a point.
Orientation. A change caused by rotation or a change in direction
Form. a change in the shape but not in the volume.
Volume, a change in total volume but not in the overall form.
Viscosity, a change in the hardness of the shape.
Texture, a change in the visual or tactile properties of the material
Spatiality, a change in the perception of a shape through repositioning.

Semi-autonomous vehicles
The context in which we deploy this research is automobility. The transition towards autonomous vehicles presents the opportunity to design for new car behavior and contexts. We chose textiles as our material because it is already being widely integrated in car interiors and because its material qualities allows us to easily mould shape changes.

Autonomous cars are vehicles that are able to perform all their functions self sufficiently and independently, still having to rely on in one external or cooperative information [15]. We will be designing for automatic level four on the spectrum where level 0 means having no driving automation and level 5 having full driving automation [15]. A level 4 could therefore be considered a semi-autonomous vehicle, meaning that the car we design for can drive on its own for the majority of time but may request assistance [16], this moment we call the transition moment. During the automated state, people in the car are believed to be engaged in other activities than focussing on the road, meaning that, compared to now, their situation awareness will change [17]. Increasing the importance of letting the user know a transition is happening. We believe that within this context shape-changing interfaces could aid in the transition of control. Therefore we will specifically design for semi-autonomous vehicles.

There are different studies that are exploring possibilities to communicate this transition clearly, including using shape changing interfaces [16]. The paper Reinventing the Wheel shows us that mechanical movements serve as a better alerting tool than merely visual queues (LED light) [18]. Others compare different potential awareness tools such as different combinations of audio, tactile and visual warnings [19]. We see an opportunity for shape change to be further explored within the context of car interiors and the communication of transitions.

METHOD
In this study we want to determine if certain taxonomies are more relevant than others when designing for a specific context. Secondly, we want to show that it is possible to use shape changing interfaces to communicate changing machine behavior. To achieve the latter (1) co-creation sessions with designers are used to create shape-changing interface outputs in the context of semi-autonomous vehicles and (2) these outputs are then classified into the different taxonomies to identify the most common ones. We aim to use this analysis to discuss whether shape changing interfaces could more commonly be used to communicate a change (transition) in machine behavior and that these can be designed for more efficiently and effectively by using taxonomies as input.

The setup of this study was inspired by the Temporal Form study [20], in which the participants were asked to generate different temporal forms with a passive interviewer present using audio and video material to document the sessions to then later be analyzed. Our approach is to generate shape changing outputs for machine behavior transitions through co-creation sessions with designers within the context of semi autonomous vehicle textile interiors. The shape-changes will be designed to take place in the mid console so that the interface can be experiences by both the driver and passenger. These sessions will be guided by a passive interviewer and will use the same documentation methods as the Temporal Form study does.
The second part of the setup of this paper is based on Morphees+ [13] which classifies shape-changing interfaces into the different taxonomies to then discuss the relevance and completeness of these taxonomies. In our case we will classify the different shape-changing interfaces created in the co-creations sessions. Following the previous, we analyze how many times and what taxonomies are used most frequently to discover if there are certain taxonomies that can illustrate this specific transition better.

The co-creation sessions
Each session took between 20-40 minutes each, depending on the prototype, pace and interest shown by the participants. There had been a total of 7 sessions in which the participants participated in pairs of two. Within the first five minutes the participants were introduced to the meaning of shape-change and the context of semi autonomous vehicles. Then a 5 minute semi autonomous vehicle scenario was shown in the form of a simple low tech simulation of a driving route in which two transitions of autonomy took place. This simulation setup consisted of two chairs, a mid console placed in between them and a route map placed in front of them showing the transitions necessary during the journey from point A to point B. After being familiar with the scenario, the participants moved on to a prototype space where materials were laid out on the table. The prototype material consisted of more traditional car interior materials, such as (fake) leather, hard cotton and some more non traditional textiles such as shiny polyester and satin. Besides the previous, some rope, scissors and other basic materials were provided. The whole session was guided and assisted by a passive interviewer, who guided the designers to reflect upon their thoughts and creations. At the same time, the sessions were audio and video recorded and used as the final output material.

The audio was transcribed and the video material was analysed to verify if any essential information was not well reflected upon or present in the audio. From the transcribed audio, quotes that describe a form, material, tactility, volume change and vehicle behaviour were then separated. These quotes were then classified into the list of the different taxonomies.

The participants
In total fourteen participants, 6 male and 8 female (age 21 - 25) were recruited from the department of Industrial Design from Eindhoven University of Technology. The reason why the participants were chosen to have knowledge about design, was because they would be more familiar with reflecting upon their design decisions and creations. Another reason for choosing designers as participants is the reason that they are more capable of exploring alternative futures [21]. These participants were required to be in possession of a valid driver's license. Even though they would not be driving in real life it was considered relevant for the designers to have both experienced what it was like to be a passenger as well as a driver.

RESULTS

To understand what shape-changing interfaces are most relevant when designing for the transition from autonomous to self driving mode we analyzed the outputs of the co-creation sessions into the different taxonomies. There were three main outputs: video material, audio material and the physical prototypes. These low-fi prototypes, all made out of the traditional materials, were taken apart after each session since they did not present a strong enough structure to be used outside of the context of the sessions. The audio material was transcribed and compared to the video material to identify any missing details or important aspects that wasn't mentioned verbally.

The transcribed audio was coded by one of the researchers with the purpose to code and then identify the different taxonomies. A separate classification was added to identify specifics about the communication of the vehicle with the user, to get a clearer picture about the communicative capabilities of the shape-changing interface.

The coded audio was used to count the frequency of each taxonomy as can be seen in figure 1. There were several taxonomies that were not explicitly shown or mentioned by the participants: closure, amplitude, strength and form. While others were almost always mentioned: texture and zero crossing**.**

In the transcribed audio we were able to detect certain specific vehicle behaviours that the designers wished to communicate. When analysing the transcribed audio we looked for terms related to emotions for example (Session 2, Participant 4) "Imagine that the car is driving itself, then it should also convey a certain feeling to the user like confidence". And vehicle intentions for example (Session 5, participant 8) "Just that the thing (the vehicle) lets us know that we have nothing to say anymore". A total of 17 quotes were gathered related to vehicle behaviour mostly expressing the need for notifications with varying degrees of urgency.

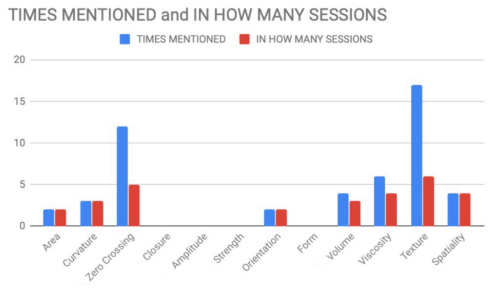

Figure 1. Table of the taxonomy classification.

DISCUSSION

The aim of this research is to identify if certain taxonomies are more present than others in a specific context, to then potentially be used when designing new shape-changing interfaces.

The taxonomies

The results suggest that in the context of semi-autonomous cars, zero crossing and texture are most relevant taxonomies.

Zero crossing (session 7, participant 14) "maybe you get to see some kind of shifting pattern so that we could all get notified" "I was actually thinking about like a wave".
Texture (session 2, participant 3) "It would be cool if it first would be leather and then some sort of interior textile".

We believe some taxonomies were not used at all because they are less appealing for this specific scenario. However there might bcce a difference between the taxonomies that weren't mentioned by the participants, why this has not been able to show might be because of the limited number of participants.

In the sessions we started to see a relationship between the taxonomies texture and zero-crossing and the desired human-like behaviour of the vehicle. They intuitively used these taxonomies more than others which show that there may be a natural inclination towards these within this context. Based on their interpretations, the participants associated these organized-wave like shapes with human-like behaviour, and texture qualities of materials with human-like intentions. According to the participants this association could enforce the user experience in the semi autonomous vehicle because it shows that the vehicle is confident which then offers a sense of security. This potential of expressing human-like emotions has also been explored and shown in the mentioned before [8] and [7]. We see the possibility of communicating the transition through shape-change, but most interestingly, we see the potential of specific taxonomy qualities being related to specific vehicle actions.

Transitions

Secondly did we want to identify whether it would be possible to communicate the moment between two automated behaviours of a machine. A clear way of communicating a binary transition in machine behaviour resulted to be that state 2 presented the opposite taxonomy qualities of state 1. For example in session 6 the participants suggested a wrinkled surface as the transition from autonomous to non-autonomous and flat and smooth surface for the reversed transition. As mentioned by Alexander et al.[2], there is still a lack of what types of changes should occur in what specific circumstances. Based on the previous, we would like to propose this finding as a design guideline aiming for consensus through the shape-change field and to avoid end-user confusion; this guideline could be applied in many different contexts.

Notifications

A recurring topic when talking about the communication between vehicle and user was the desirability of knowing how far along the transition was. Since people had to fully rely on the vehicle when in automated mode they felt the need for the car to indicate the urgency or how fast the takeover was going to take place. The way in which this was explored during the sessions was the use of gradual changes in the velocity of shape-change of the surface. (Session 2, participant 3) "When the scales (independent pieces of fabric and leather) are not totally turned all the way you can see that the transition is not done yet". Participants also referred these moments as notifying and were explored in the form of variations in the kinetic movements of the shapes. As Haodan Tan et al. discusses in Happy moves Sad groves [8], the kinetic properties of shape changes have an impact on people's emotional association. Another way this urgency has been explored is through an increasing and decreasing change in volume of the shapes in the transition. This shows us that the perceived amplitude of the shape could contribute to the overall awareness of the timing of the transition. The importance of urgency in the handover by the semi autonomous vehicle has also been concluded by van der Heiden et al. [22] in their study to identify how auditory pre-alerts can influence the success of the handover. We have both been able to identify this need, additionally we also offer different methods that can convey this urgency.

LIMITATIONS AND FUTURE WORK

This paper was a first attempt to understand the relevant aspects of a shape-changing interface when wanting to illustrate the transition of manual to autonomous diving and vice versa. The analysis of this paper suffers from the limitation of merely taking into account one way of shape-change classification, which could potentially influence the perception of the relevant aspects of shape-change in this specific context.

Another limitation in the analysis is the fact that the outcomes of the co-creation sessions have been classified by a single individual allowing a bigger margin for error. We consider it of value that these outcomes would be classified by multiple other experts to increase the studies reliability.

Even though the first fourteen participants were designers and were able to implement design thinking they did not have a specific expertise related to the research topic. This could have an influence on the quality and reliability of the discussion outputs of the co-sessions. On the other hand this could also be beneficial proving potential new insights inspired by other fields of design.

In future work, investigating the dynamic qualities of shape-changing interfaces for these specific taxonomies might prove relevant. Other important studies might include a deeper study into the specific material qualities and its influences on the perception of the shape-changing interface. Lastly, we propose a study that investigates the potential of complementary sensory elements such as light and sound to enhance the overall transition experience.

CONCLUSION

In this paper, we presented a study that explore the potential of taxonomies as descriptive input to design shape-changing interfaces and the communicative capability of these interfaces to illustrate automated transitions, in this case hand- and takeovers for semi-autonomous vehicles. Based on our findings, we see an opportunity for taxonomies, zero crossing and texture, to be used as input to design certain machine behaviours (transitions) and shape-changing interfaces, more generically, to be specifically used to communicate the urgency and how far along the transition is.

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