Evoke: an Explorative Project to Enrich Connectedness for Elderly through an Embodied Intelligent System in Social Context.

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ABSTRACT

This paper builds upon the PhD project 'Uitkijkpost' of Xu Lin, executed in the Industrial Design faculty of the TU/e. Within the elective 'Embodying intelligent behavior in social context', the original Uitkijkpost concept was revised from a different angle. The interaction was redesigned, addressing the problem of inability for the elderly to interact with the outside world.

The process of redesigning eventually led to the concept 'Evoke'. This includes an agent in the shape of an intelligent driving robot, which aims to provoke reactions through its embodied behavior within an outside world environment. The robot is meant to increase the interestingness of live video footage displayed within a communal care-home space, and learns from positive and negative inputs of the elderly living there.

Evoke is designed by going through an iterative design process with a focus on embodiment and technology. The outcome of this project contains of a relatively extensive variety of embodiment concepts through movement in combination with a 4-dimensional SVM prediction algorithm, both applied to a social interaction concept.

For further development of Evoke, the concept should be improved and then evaluated with the actual users, the elderly at the Vitalis elderly home. Therefore, new iterations in both the interaction of the elderly- and sharers with Evoke can be explored and evaluated further.

1. INTRODUCTION

1.1 Vision

Nowadays, robots are making their way into households more and more [13]. Looking at the use of robotics for elderly, this might offer interesting opportunities for the future, especially regarding social robots. Herein, the functions and behaviors can be adapted (using embodied intelligent algorithm) towards the elderlies personality and needs. Below, three examples are proposed of what these could be:

1) Robots which will provide entertainment for the elderly. Sun *et al.* pose that elderly are only safely surviving and not actively living, when they are assisted by assistive devices without the communications with the outside world [11].
2) Robots which can establish more social relations for the elderly since elderly quite often struggle with connecting to others. The way they are connected or with whom, can be learned by the robot. There are already interventions trying to prevent social isolation, but there is a very one-sided offer of services and interventions. Many of the interventions do not connect adequately to the specific circumstances and needs of the target group, so the proven effects remain small [3, 6, 7].
3) Robots which will be a complete social buddy for people living alone. The behavior of the robot is rather important here since it should be able to mainly take over the role of the former partner. Personalization and embodiment is therefore a key in these kinds of designs, where it should be taken into account that a robot would not need all the functions and appearances a human has, since people already give every object they see a personality [9].

Besides, from a designer point of view, a vision on the future of embodied intelligence was developed as well. The core part of this vision, that was gained out of this project, is that designers do not have to think about certain details anymore and can make less assumptions concerning interaction scenarios for the user; the product can namely independently learn this over time. What is meant by this vision is that where before the user was centralized in the design process, designers in the future would not have to worry about it that extensively any more. The design will learn from the user and adapt to every person individually. This can prevent making wrong assumptions as a designer and eventually might shift the role of designers and can evolve into a new design revolution.

Adding up to this, personalization of products and systems is becoming more and more popular. This is especially important when designing for the elderly, since their needs, attitudes and wishes differ strongly. The personalization in this envisioned future is thus not determined anymore by the designer, but simply uses the intelligent learning algorithm.

Throughout the process, the project's future vision on embodied intelligence has developed itself and gradually obtained a deeper layer. Initially it was used as an ideating tool for the concept, whereas later on the vision was a drive behind the conducted design approach. Moreover, the vision is eventually also the abstract message behind the final design Evoke.

1.2 Related work

Looking at related work for this project, existing research on robotics and elderly was investigated. The primary focuses of this research were the emotional and social aspects on what robots can establish. Besides, this project's main source of inspiration, the Braitenberg vehicles, is shortly introduced.

In the study of Shibata *et al.* experiments were performed with bringing in pet robots in the elderly environment and measuring how they would react on this [10]. The main part drawn from this research for the Evoke project, is that the appearance of a robot influences how people are expecting it to behave. Therefore the use of specific details should be taken into account when designing the appearance of the robot.

Kidd *et al.* conducted an experiment in nursing home settings with small interactive robots, researching how these could encourage social interaction among the elderly [8]. Interesting here, is that having something in common to talk about, can stimulate social interaction among elderly. Furthermore, it can result in feelings of importance and positive self regard. These findings can be used both as grounding for the concept and as inspiration for its social interaction.

Considering the embodiment aspect of this project, Braitenberg is one of the closest related works and inspired the ideation process of this project [2]. He designed vehicles (with only two lighting sensors) that can perform different kinds of behavior (coward, aggressive, love and explore). In his paper, he wrote: "Interest arises, rather, when we look at these machines or vehicles as if they were animals in a natural environment. We will be tempted, then, to use psychological language in describing their behavior." The most interesting finding herein was that movement results into behavior that can trigger emotions.

In extend to emotional triggering movements, Barakova *et al.* have created a framework that connects car-movement specifications to cognitive emotions [1]. This can be used for validation purposes for the embodiment aspect of this project.

1.3 Problem and Solution

Uitkijkpost, a PhD study of Xu Lin, is the project that initiated the development of Evoke. The goal of Uitkijkpost is to bring the outside inside for the elderly living in the elderly home of Vitalis. It addresses sharers who take a camera with them when they go outside. This camera will take photo's of the environment, which are subsequently viewed at three screens in the communal space of the Vitalis elderly home. When the elderly like the picture that they see, they can press a button underneath the screen to print a postcard. The idea was that this postcard could then be sent to the sharers by the elderly as a thank you (Figure 1).

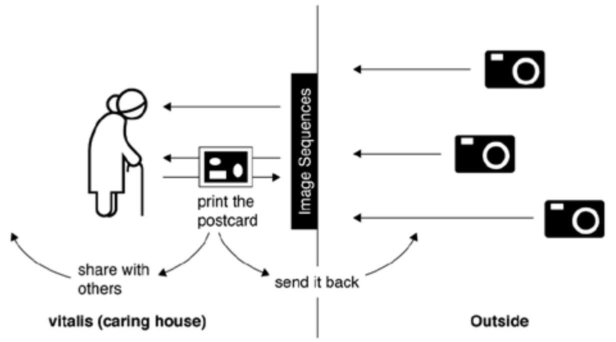

Figure 1 - Uitkijkpost infographic

Building on the idea of Uitkijkpost, the concept of Evoke aims to explore how one could utilize embodied intelligent algorithms to enrich the scenarios where the elderly people in the nursing home would feel more socially connected with both their environments and the outside world.

The main improvement goal was to increase the value of what they see on the screens and to give them independency over this footage, by means of actually letting them have an influence on what happens outside. A low threshold interaction, which easily allows the elderly to have control over the footage, had to be designed. Where now the footage consists of static photo's, the concept of Evoke works with live video footage to give a more realistic image of the outside world.

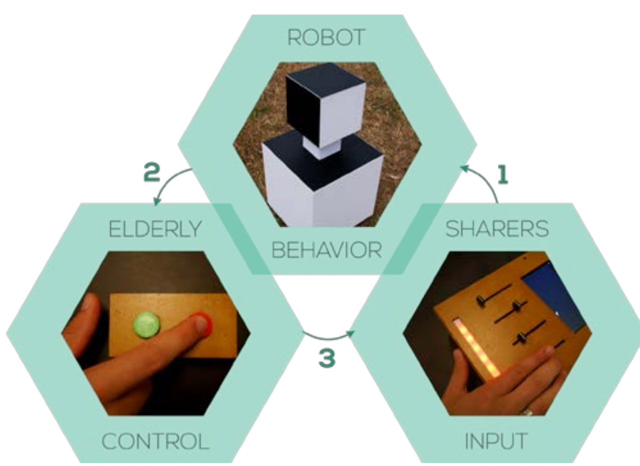

Figure 2 - Concept loop visualization

As a valuable addition within the project, embodiment is added. A moving robot is placed outside the elderly home by the ‘sharers’. To give this robot behavior (Figure 2 - 1), the sharers have control over four sliders with numerous possibilities, each forming its own human-like behavior. The different kinds of behavior will evoke different reactions from the outside world, which can result in more interesting footage for the elderly (Figure 2 - 2) and makes them capable of actually changing things in the outside world.

When tweaking the sliders, the sharers get feedback from the lights on the bottom of the panel. These lights indicate whether the behavior they are setting is probably going to be liked or not by the elderly. This is done by using a Support Vector Machine (SVM) algorithm which uses the input from the tool for the elderly on which they can easily like or dislike the behavior (Figure 2 - 3) of the robot that is acting in its social context. The sharers can see a simulation of the behavior on the screen of the panel, and if they want to send the behavior to the robot, they simply press the button next to the screen.

The robot and its surrounding are recorded from a bird's eye perspective and livestreamed on a big screen in the elderly home.

Evoke can have an impact on both the elderly and the outside world. Increasing the social involvement amongst the elderly and the involvement they have with the outside world can establish a feeling of importance and can positively improve their self regard. Furthermore, Evoke will elicit behavior and reactions of its surrounding. The subjects (children, animals, students etc.) are each time influenced differently, as their reactions on the robot’s behavior are dependant on their personal mood, context and cognitive processes.

2. Background information

2.1 Design approaches

In order to pursue the meaningful involvement of embodied intelligence, a both design-oriented and technology-oriented design approach was used.

In the beginning, the ideation was mainly conducted through a design-oriented approach where meaningful embodied interactions, that could evoke social behaviors from the elderly, were conceived. Building upon the original agent that connects the elderly and the outside world, a concept was made of a moving robot that could provide more interesting video footage. By making the robot act within a communal environment, the expectation was set that social behaviors from both the elderly and the people outside could emerge, which will be elaborated in section 2.3 of this paper.

After the vision was set as outlined above, a technology-oriented approach was taken to see how learning algorithms could help enhance social aspects like provoking emotions and initializing communications. Inspired by the Braitenberg vehicles project [2], a two-wheel system was developed to facilitate the expression of emotions, through different settings of the four parameters of the wheels (orientation, velocity, turning angles, and steadiness). Using SVM classification algorithm, the system could learn the “taste” of the elderly through having them express their feelings of like or dislike towards the current behavior of the robot. As the system keeps learning, it would get smart enough to give the volunteers who set the robot behaviors a hint of whether the setting would possibly be appreciated by the elderly.

2.2 Iteration process

From the initialization of the vision to the final concept, there were two main concept iterations that attempted to reach the goal of social involvement and embodied intelligence through different ways.

The first iteration was initialized with the goal of evoking more social behaviors inside the nursing home, while maintaining a low threshold of interaction for the elderly. A semi-aware interaction system was conceived, with ambient sensors that gather inputs from the elderly to influence the behaviors of a robot that carries a camera. The possible inputs could be the sound volume, the positioning or the crowdedness within the elderly nursing home. An example of the scenarios is outlined in Figure 3.1: in the upper part, the elderly people are sitting in groups in communal space, causing the robot to search for groups of people outside; on contrast, if they sit more separately, the robot would keep a distance from the crowd. In this way, it was envisioned that there would be more social interactions like communication provoked.

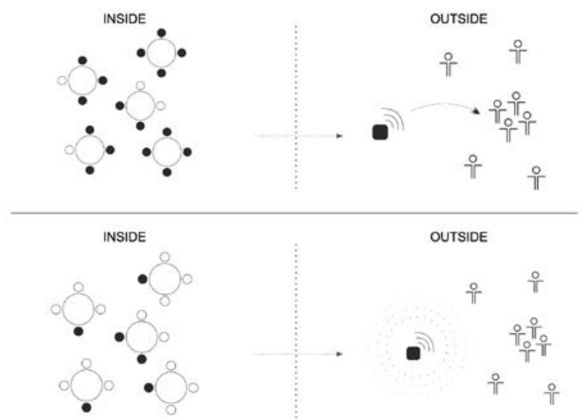

Figure 3.1 - Examples of iteration 1 interactions

After the first iteration, it was assumed that the elderly would love to have more impact on the outside world. Moreover, there was a concern that ambient sensing for the elderly would be too abstract and indirect. Therefore, keeping the same vision of evoking social behaviors, a new idea was proposed to let the elderly influence the behaviors of the robot through different patterns of clapping hands (Figure 3.2). It was, however, difficult to assign meaningful behaviors to different clapping patterns. This kept the interaction threshold high and would still make it abstract and indirect for the elderly to see the mappings.

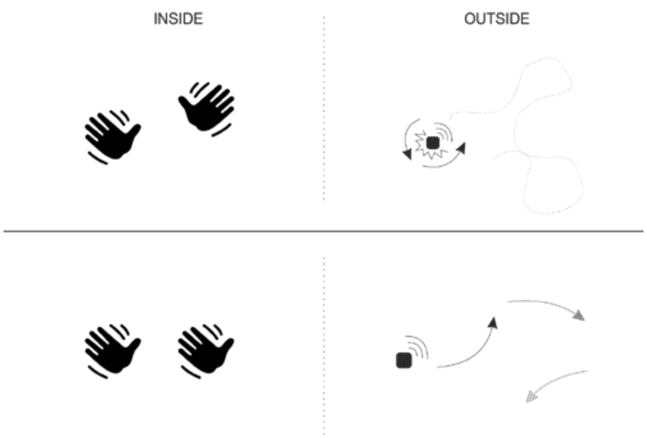

Figure 3.2 - Examples of iteration 2 interactions

Reflecting on the previous two iterations, two aspects that are crucial for the acceptance of the concept are the threshold of interaction for the elderly and the directness of mapping between robot behaviors and interaction patterns. In the final concept, these two aspects were balanced, which means the interaction threshold was kept low and more directness mapping between the inputs from the elderly and the robot behaviors was established.

2.3 Social behaviors

Looking at the final design, social behaviors emerge in the following three ways: firstly, the robot acting as if it has human-like emotions [1] (more detailed explanation can be read in section 3.2) can provoke emotions among the elderly, which stimulates them to initialize conversations with each other; secondly, collaborating behaviors could emerge as the elderly sit together and influence the behaviors of the robot through acting collectively; lastly, there would be joint attention evoked among the elderly and people who are attracted by the behaviors of the robot, which gives the elderly an enhanced feeling of having impact on the outside world and makes them feel more connected.

In embodied cognition theory, the forming of concepts shifts when it's perceived by different people in different contexts [12]. In this project the concepts are being formed by the cognitive processing of the robot's behavior. This leads to certain perceived emotions within people, varying for each individual. This perceptual difference applies for both the externally located elderly and the people or animals involved in the direct interaction with the robot. Therefore, there would probably not be a single robot behavior that is persistently liked or disliked by the elderly. It depends on both the people's reaction on the robot's behavior and the elderlies perception of this reaction and behavior. Implementing a continuous training algorithm of the robot's behavior would therefore be an adequate solution for the Evoke concept.

2.4 Learning algorithm

At first the Q-learning algorithm seemed right for this project to create an intelligent system that would make the Evoke robot behave in an explorative and optimized manner. The Q-learning seemed a good fit for the project because of its gamma value (Figure 4); a value between 0 and 1 that determines how eager the algorithm is in making the most optimal choices along the path. Reducing the gamma value would increase the 'explorative behavior' of the robot. Hereby, the robot could act according to the elderly input and try out new behavior now and then to increase its variety. Doing this, however, could also be done by means of a rating algorithm that doesn't require any intelligence. Moreover, another reason why the Q-learning turned out not to be the right choice was that the Evoke concept depends upon working with many features and a labeling system of like and dislike. The first idea was to use these likes and dislikes as treats for the Q-learning. This however seemed not to give the desired result as the likes and dislikes are only send once in awhile. This would result in Q-learning without a treat (like) and punishment (dislike), which means that the Q-learning doesn't have a desired path to follow to end up at its goal. For the Evoke concept not the sequence of-, but the behavior itself should be optimized.

$$Q(s_t,a_t) \leftarrow \underbrace{Q(s_t,a_t)}_{\text{old value}} + \underbrace{\alpha_t}_{\text{learning rate}} \cdot \left(\overbrace{\underbrace{r_{t+1}}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1},a)}_{\text{estimate of optimal future value}}}^{\text{learned value}} - \underbrace{Q(s_t,a_t)}_{\text{old value}} \right)$$

Figure 4 - Q-learning formula

A SVM algorithm, in contrary, seemed to allow for all the aforementioned criteria. SVM allows the system to have multiple input features, which can be classified as liked or disliked. This way it is not the sequence of features that is evaluated, but the behaviour resulting from these features.

Therefore, the choice to work with like/dislike (0 or 1) as labels for the SVM classifying was made. These labels are used as input to create a trustworthy prediction over time, which is the output of the SVM.

The decision was made to work with RBF SVM instead of the linear SVM, whereas it was not expected to find a linear distribution between the data. The data was not expected to be linearly classified, because of the varying perceived emotions described in the last chapter. One can therefore conclude that for this purpose, a nonlinear division would create a more accurate division.

3. Design

3.1 Design of interaction - the social context

The 'Uitkijkpost' project is about connecting elderly people to the outside world. The elderly are often unable to travel independently, and are therefore limited to the context of the care home. There are several distinct areas within this context, each with their own characteristics. Whereas individual rooms are relatively unsocial and have a lonely image, the lobby or restaurants strive to connect elderly and stimulate social contact.

Evoke was designed with the goal of improving the Uitkijkpost interaction scenario. Throughout the process of developing Evoke, multiple interactions were explored. This explorative process was described in the iteration chapter and eventually resulted in the final social interaction.

According to the Activity Theory [4], a social interaction can be divided in three steps; the Motive (M), the Goals (G) and the

Conditions (C). The Evoke concept intends to entertain elderly people and connect them to the outside world (M). To achieve this, interesting video footage needs to be created through specific robot behavior in a social context (G). Therefore, the robot has to be accommodated with multiple kinds of behavior (C_1) and a clear indication of the elderlies preference needs to be obtained (C_2).

The Activity Theory furthermore also includes looking at concrete activities, actions and operations. These more specific and direct aspects of the social interaction of Evoke have been described within Activity Systems [5] (Figure 5) and together form the activity network of the interaction..

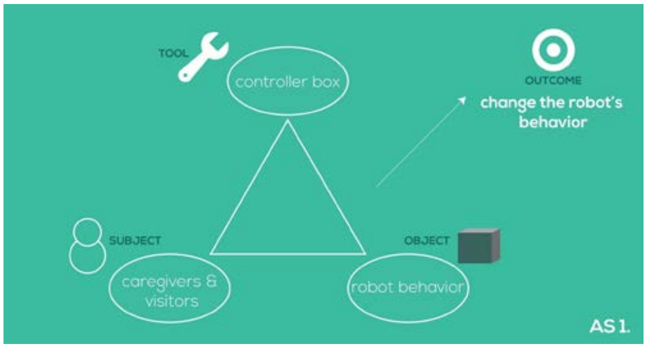

Figure 5.1 - The caregivers and visitors program behavior into the robot

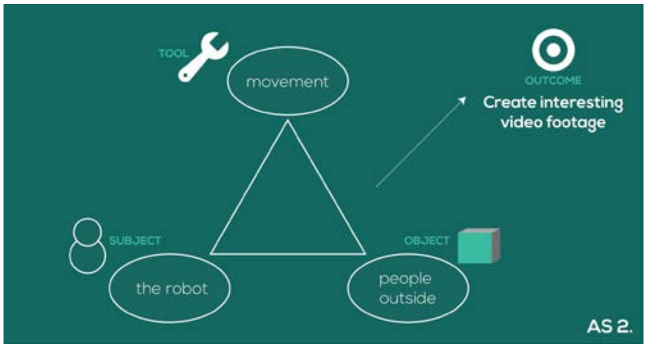

Figure 5.2 - The robot influences the people outside to create interesting footage for the elderly

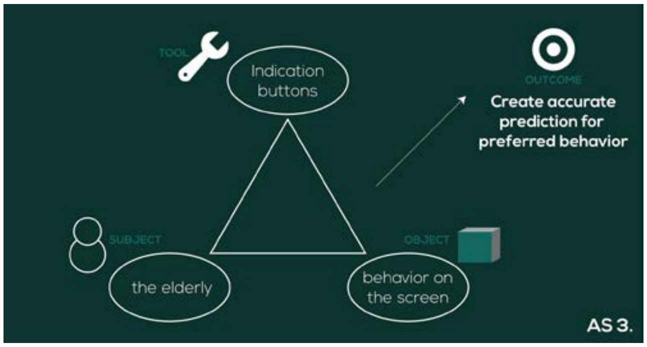

Figure 5.3 - The elderly indicate what behavior on the screen they find interesting

3.2 Intelligent behavior and embodiment.

SENSORS

The prototype of Evoke consists out of a control panel, a like/dislike panel and a robot (Figure 6).

On the control panel four sliders are located which respectively represent the speed, orientation, turning angle and steadiness of the robot. Besides the sliders, a screen and a RGB LEDstrip are present on the panel.

The separate like/dislike panel contains two buttons that are pressed by the elderly according to their emotional response. These two buttons represent a simplistic interface that is easily understandable and may result in a low threshold interaction. Combined, with the four sliders, these form the five inputs used in the SVM (sliders 1, 2, 3 and 4 in combination with the like/dislike label).

The sliders are connected to the Arduino Mega (Appendix A) and send a value to the analog pins of this Arduino Mega and to an Arduino Uno. The Mega is used to connect the sliders to the learning algorithm and to communicate with the robot. Based on the slider values (input) the Arduino Mega will use the SVM to retrieve the predicted label (output) matching these values. The label is the predicted preference of the elderly: like/dislike. When this label is 1, the LED strip will become green. When the label is 2 the LED strip will become red. To send the values of the slider to the robot, a push button on the control panel can be pressed. Through XBees (Appendix B), the values are then wirelessly sent to the robot.

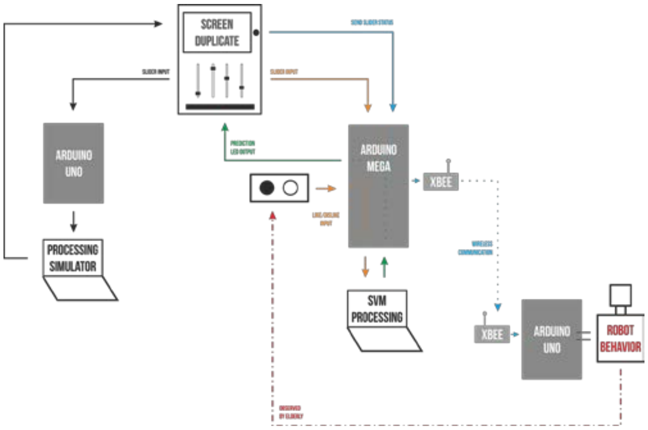

Figure 6 - Technology prototype visualization

The Arduino Uno (Appendix C) is used to create a visualization (Figure 7)(Appendix D/E) of the behavior of the robot based on the values of the sliders. In the simulator app, a moving white circle that leaves a trace is used to mimic the movement of the actual robot. The four slider values are sent to the app and change the values of four virtual sliders. The actual values are displayed on top right of the interface to give the people who set the robot behaviors an overview of the robot's status.

When the values of one of the like/dislike buttons is high, the slider values and the label matching with the button is send to the SVM (Figure 8). When there is no button pressed, only the slider values are send

Figure 7 - Simulation visualization

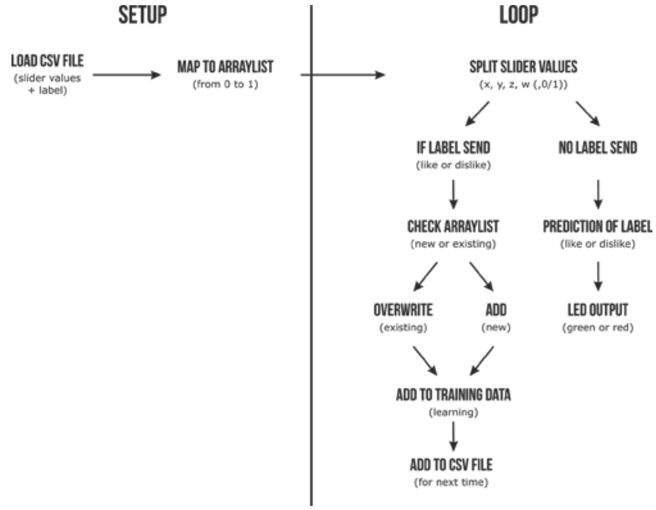

Figure 8 - SVM visualization

SVM ALGORITHM

The SVM algorithm within this project is runned in the Processing software. The Processing code (Appendix F) uses the SVM4P library of dr. J. Liang and contains an external CSV file to store the input data. In this chapter a brief overview of the SVM functioning is given, supported by a visual (figure 8). More explicit and detailed information can be read within the appendix (appendix G).

The Processing sketch loads a CSV file, to either make a prediction based on existing values or store new values. Meanwhile, continuous sensor data is received. There are two types of incoming data; labeled data and unlabeled data.

Most of the times, the program receives unlabeled data. This kind of data is send all the time and contains the slider-values of the controller box. When it receives these values, it checks on which side of the SVM classifier the specific setting is located and returns a prediction based on this. If it returns a positive prediction, green LEDs will light up below the sliders on the controller. This shows that the current setting is expected to be liked by the elderly. Otherwise, in case of a negative prediction, red LEDs will light up.

Besides unlabeled data, the program can also receive labeled data. This data is send when the elderly press the like or dislike button. When this data is received for a new kind of behavior (a new unique slider setting) that has never been labeled before, a new data set is added to the CSV file. It can also happen that the received setting was already labeled before. In this case, that specific setting will be overwritten with the new label that was given to it. In both the 'adding' and 'overwriting' cases, the SVM classifier will be recalculated and shift accordingly. This entails the learning process of Evoke.

SVM RESULTS

To have more support in the beginning of the programming only two slider features and the label were used to visualize in a graph (Appendix H). This graph was used to visualize the results of the RBF SVM, which would not have been possible with more than three features, as this would result into a 4-dimensional visualization. The results showed a perfect division between the two different labels and the predicted label based on a set of training values (Figure 9).

The moment everything worked well in the 2D environment it was decided to scale everything to a new SVM that would make use of four features and the labels. This showed the relevance of the 2D example, whereas now it was not able to verify the results of the prediction, since a visualisation was not possible anymore.

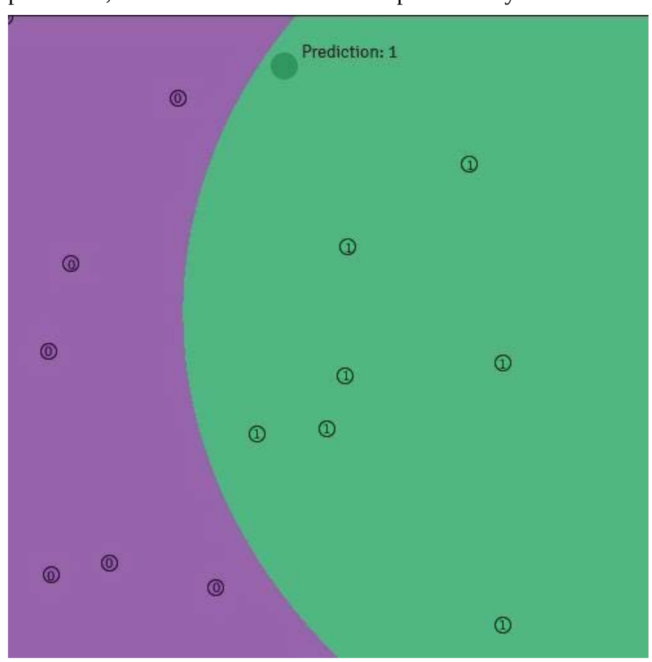

Figure 9.1 - SVM prediction 1

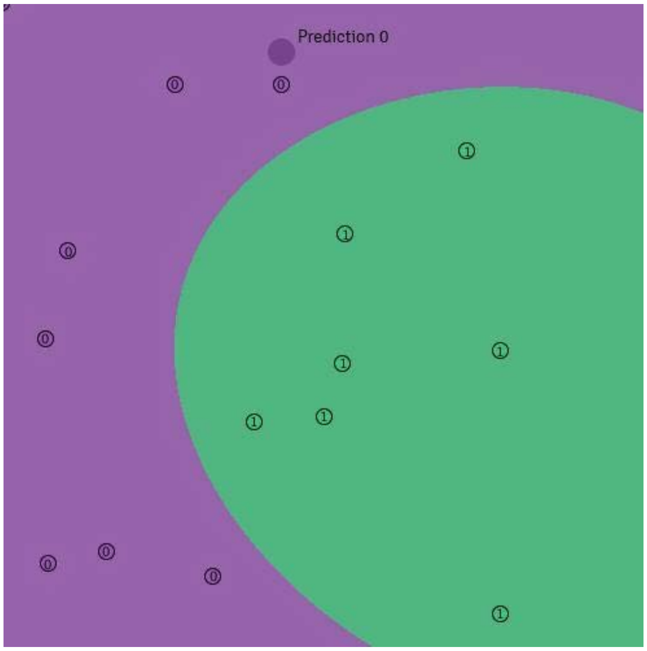

Figure 9.2 - SVM prediction 2

EMBODIMENT

The robot consists out of two wheels that operate relative to each other. By manipulating the 4 sliders, different driving behaviors can be programmed into the robot. These behaviors are therefore simply based upon inputs that drive the motors inside the robot. However, the movement patterns that follow out of this can provoke emotions and can be seen as more than just driving behaviors. This entails the embodiment of Evoke.

As for the movement, the first slider adapts the orientation of the two wheels, whereas the second slider adapts the velocity of the wheels. The third slider decides the turning angle of the robot. Where a high slider value will result in faint curves with a big rotation angle, a low value will result in sharper curves with a small rotation angle. This is done by changing the relative speed between the two wheels.

The last slider decides the steadiness (shift frequency) of the robot, where it defines the fixedness of the slider values. All the values have a margin (b) around the fixed slider value (value x =x ±b). When the fourth slider is low it means that it takes long to change the b, which means the robot keeps performing the same movement. If the slider is high it will change the b value more frequently, which makes the robot change its behavior relatively often.

Zooming out, The robot's movement is being unconsciously compared with human behavior and fosters an emotional response within the human brain. The physical form of three stacked cubes that are moving in a particular way suddenly becomes an object with a certain characteristic; a certain mood and personality. Its actions, physical shape and context play a significant role in the cognitive processing of the robot within the human brain. This causes a deeper layer of thoughts, which links and compares the behavior with previous experiences and known concepts.

On the right, four more explicit examples of how the embodiment is being implemented within the Evoke concept are given (Figure 10). Each visual shows the resulting behavior of a specific slider-setting, accompanied with a possible associated abstract characteristic. These examples are just a small range of possible options, and are meant to demonstrate the possibilities and variety of the robots embodied behavior.

The robot has a relatively basic shape, limited interaction possibilities and little details, which makes it not very humanoid. Through its affordances, an attempt is made to communicate its functions. Striking, herein, is that it has no eyes or hands. While this would make it more humanoid, in its current shape it would communicate false information that can lead to confusion and distract the humans cognitive processing of its embodied message [9]. When the robot would have been provided with eyes, people would expect them to act in line with its movement. As long as the robot could not fulfill the set expectations, the added affordances would reduce its communicational and interactive strength [10].

While adding eventual eyes would decrease the value of the embodiment in its current form, the covering of the wheels increases this value. It results into the fact that one does not see the car and the physical topping as two separate aspects. The car is integrated within the robot, so that people are more likely to see it as a robot that is moving and acting independently, rather than a car with a robot on top. It gives people the feeling that 'it' is acting, instead of 'it' is being acted upon; it enhances the feeling of an individual with characteristics.

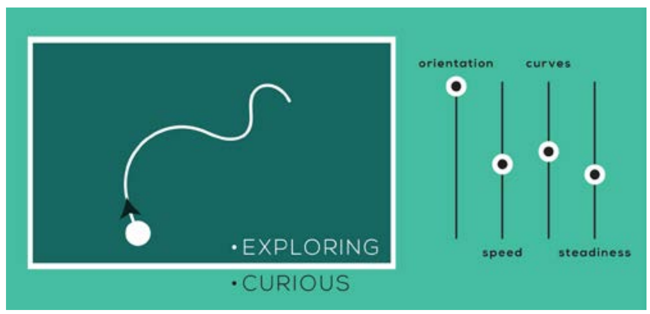

Figure 10.1 - Embodiment behavior 1

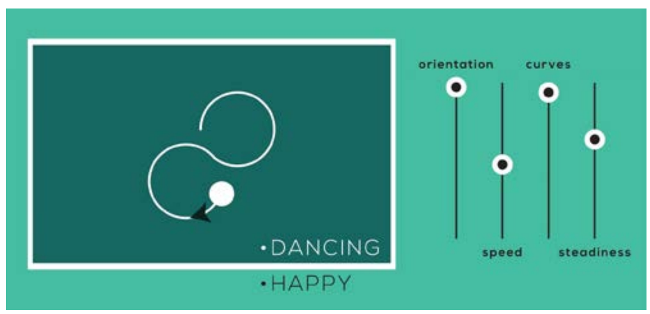

Figure 10.2 - Embodiment behavior 2

Figure 10.3 - Embodiment behavior 3

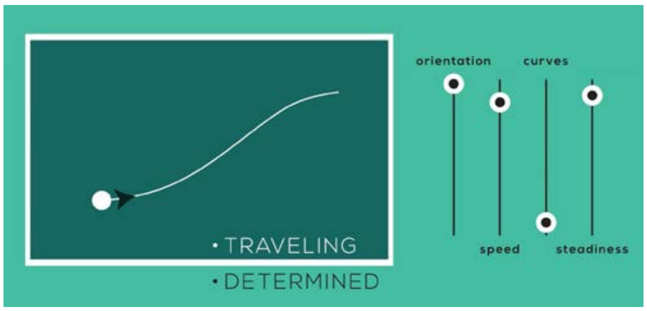

Figure 10.4 - Embodiment behavior 4

3.3 Testing and analysis

In the current state of the project, mainly due to time constraints, the technological and learning aspects of the concept were tested and validated only with the designers of the concept, not the intended users. The results of the interaction elements in the prototype are as expected, as well as the prediction from the SVM. Adjusting the sliders directly influences the visualization on the controller and, when sent to the robot, the robot's behavior. By pressing the like button for a certain combination of slider values, future predictions for similar movement patterns received the same label, and vice versa.

However, for actual validation, user testing with the elderly for whom this system was designed is crucial. All design decisions for this concept are based on previous knowledge and empathy, which only works to a certain extent. In a potential future study, the usability and added value of this system should be tested and validated.

Due to the learning aspect of the system, such a study should be performed over an extended period of time. This setup should improve usability results as well, since it allows the participants to get somewhat familiar with the system. Regarding the value this system adds to the user's life, as well as general user experience, personal interviews in combination with questionnaires would be performed at the start and end of the study. As far as usability with the Evoke system goes, interaction with the system should be observed to check if the users understand it. All results combined would lead to conclusions regarding effectiveness, usability and potential improvements on the system.

4. Outcome and Conclusion

For the overall concept of Evoke, an important goal was to design for a strong embodiment and a good implementation of a learning algorithm. Looking at the social goal of Evoke, it aims to add more value to the scenarios the elderly perceive on the screen in the lobby, enabling them to interact with the outside world and enhancing the mutual elderly connectedness.

Because of the fact that the robot has not yet been tested in its original context, it is hard to draw any grounded conclusions. However, there are a few things that can be concluded without this testing data. In order to function and test in a communal environment with people from outside, the robot needs to be significantly improved. It lacks a camera-vision or distance sensors, which causes it to potentially run into any object, animal or human that passes by. In addition to these practical concerns, the lack of robot-vision also reduces the quality of the concept. Due to the blind movement of the robot, it cannot respond or explicitly interact with its environment. The limitations that it brings along are elaborated upon within the discussion section below.

Furthermore, one can conclude that the robot might need a more intuitive control-panel that takes into account and processes the feeling of embodiment. At this moment, it is provided with simple sliders that are hard to grasp in the context of embodiment.

The SVM learning algorithm, that was used to train the controller panel through the input of the elderly, turned out to work sufficiently. Although it is hard to visualize 4-dimensional data, both the 2-dimensional visualization and the 4-dimensional data show a good functionality of the system. Looking at the embodiment of this concept, one can also conclude that the results show an extensive execution. The movement could be translated into a deeper layer through cognitive processing, offering many possibilities for variety. While the movement embodied results are in line with the proposed framework of Barakova (2010), there has not been a validation test among the elderly users of this project. As for functionality with regards to the social context, it is also still uncertain whether the desired outcome has been reached. The elderly might not feel comfortable interacting with the buttons and there is a possibility that the sharers either do not understand the control panel or find it too much effort to place the robot in an outside environment and guard it.

5. Discussion

In order to discuss the project, there are a few interesting things to reflect upon. These reflection points are explained and described in this chapter. Concept wise, the liking behavior can be questioned. The elderly namely have to indicate whether or not they like the current footage that they see. This footage is based on a few aspects; the robot's behavior, the environment and the interaction of the robot with its environment. When the footage becomes more interesting due to the preference input of the elderly this might introduce a common subject to talk about, which can result in more social communications [8]. An important question though, is which of these aforementioned aspects counts strongest for the elderlies indication behavior. The current concept relies on the fact that the robot's behavior and the interaction of the robot with its environment have a significant influence on the elderlies input. In this case, the environmental influences will be filtered out over time due to the reinforced learning process; the continuous learning loop. However, it can be that the environment is of such importance for them, that the robot's behavior and interaction is almost neglectable. If the latter is at play, the concepts intelligence has no further added value.

In an ideal situation, the robot would first search for interesting surroundings, and then act within these surroundings to provoke reactions. However, due to the fact that the robot does not have any visual sensors, it is unable to explore its environment. It just has to act on the spot where it is located. Adding certain visual sensors therefore helps to strengthen the concept, and increases the trustworthiness of elderly input. All of the behaviors will then namely take place in similar environments, so that this decision-aspect is somehow filtered out of the results.

While the SVM algorithm of course adds certain value to the concept, other learning algorithms might even better support the social interaction and strength of the concept. An important point for discussion is whether elderly will still like the robot over a longer time. Herein, one can see the prediction SVM as too limiting or too less exciting. An interesting opportunity for this is to make use of an unsupervised learning algorithm, in which the robot gains new behaviors by interacting with its environment. It can learn from acting and keep innovating itself over time, providing more exciting and varying footage and decreasing the burden on the caregivers, since manual input would no longer be required. Through unsupervised clustering combined with trial and error training, the robot will learn how to behave in a social context and keeps learning throughout time. It is, however, important to consider ethics and governmental rules in this case, as the robot is not meant to cause any harm or behave inappropriately.

As explained within the conclusion, the current controller for the robot might not be ideal. This controller is based on movement input rather than embodiment. Using the embodied terms that are gained from the cognitive processing, i.e. 'afraid' or 'happy', can make the controller significantly more intuitive. Users can then for example shift between different moods of the robot, or configure its characteristic by combining multiple characteristic-aspects. Moreover, one can also build the controller in such a way that the slider inputs are based upon the environmental reactions derived from the robot interaction. In this case, the robot first needs to act within its environment, and can make use of supervised learning to gain classification parameters of environmental responses.

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7. Appendix

Link to the google drive folder with the appendices of this project: https://drive.google.com/open?id=0By5y78cN3D1qLXVReWFNMjBfM1U