Synthetic Emotions Bicycle (SEB): Building a Human-Bicycle Emotional Bond Through Abstract Expression of Affect

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Abstract

This study focuses on the possibility to create emotional bonds between bicycles and humans. An emotional bicycle (SEB) was built for this purpose, by considering the needs a bike would have, its attributed personality and the emotions it could develop throughout usage. The emotional model used for SEB was designed with a Homeostatic approach, in resemblance of a living organism, and based on the dimensions Pleasure and Arousal. The emotional response from the bicycle was represented with Abstract Expressions of Affect, a novel field for expressing emotions. In order to evaluate the effectiveness of this model we analyzed the interaction of human subjects with the bicycle during one day while performing normal activities, as they would do with their own bicycle.

Keywords: Abstract Expressions, Emotion, Bicycle, Homeostasis, Dimensional Theories of Emotions

1. Introduction

Ever since my arrival to The Netherlands, I found particularly interesting the role that bicycles have in the every day life of people here. And also, how challenging it has been for me to adopt this means of transport, because despite learning to ride a bike as a child, it still felt unfamiliar to use one on daily basis. Hence, some questions rise: could an emotional bond between a bicycle and its rider be created? And if so, can abstract affect expressions facilitate the creation of a bond between a bicycle and its owner? If it were possible to know how a bike "feels" then perhaps the rider could develop a deeper empathy and concern towards it and hence, improve the interaction/use of it. Therefore, this project aims to research the relation between a bicycle and its owner through the use of Abstract Expression of Emotions and analyze the interpretation that people could have of the representation of the bicycle state of affect. In order to do this, several premises have been taken into consideration.

First of all, it is clear that a bicycle is an inanimate object, and similarly as it is done in Affective Learning, where one of the objectives of machine learning is that a system will help the user gain a deeper understanding of the learning process and uses it to adapt his or her behavior[16], an emotional bike could help the rider understand better the use given to the bike. This could perhaps improve the rider's safety if he/she is more aware of the performance and maintenance of the bike.

Second, to facilitate the study of the affect state of the bike, a metaphor of a horse has been used, in that way by relating this object to an actual living being it is feasible to analyze the possible link and interaction between the bike and a rider.

Third, Abstract Expressions of Emotions is a novel method of emotion synthesis and it is also an aim of this project to research further the implications and possibilities of its use in objects that users commonly interact with.

Finally, it was necessary to adapt a bicycle to make it able to express a state of affect determined by its needs and drives. This bicycle is called SEB (Synthetic Emotions Bicycle).

2. Related Work

Emotion Theories attempt to explain the origin of emotions, the simulation of these theories in robots, computers, agents or machines in general allow the generation of artificial or Synthetic Emotions. To achieve the generation of synthetic emotions in the bicycle we have selected an Emotional Model and a mean of Affect Expression that will be addressed in this section, along with similar study cases.

2.1 Emotional Model

How would people perceive the state of the bike is highly related on the Emotional Model applied. Darwin proposed in his book "The Expression of the Emotions in Animals and Man," that many species share similar emotional experiences – fear, pain, pleasure, affection, anger – and express them in similar ways through multi modalities[4].

When it comes to classification of emotions, Dimensional Theories propose that emotions can be classified in a dimensional space[15], the most common are pleasure and arousal where for example sad is of low pleasure and low arousal, while happy is high pleasure, high arousal. The purpose of applying this model to the bicycle is to make it possible to map the use given to a bicycle to dimensions that can represent emotions, for example speed could directly affect the level of arousal and the closeness to the optimal speed could be translated into pleasure.

Homeostasis is the tendency towards an equilibrium of physiological elements, an Homeostatic approach on robots or agents allows them to represent a state of affect and react to changes in the environment [10]. Designing a model based on the needs and drives of an agent can help model its behavior and emotional state, because the way the environment affect the agent will allow it to fulfill its needs and react accordingly e.g. For an agent with a need to move, it will require energy to do so, if this parameter is not enough then the need is not achieved which will give rise to emotions such as sadness, frustration or even anger. In the case of a bicycle, needs and drives are understood as the characteristics that will influence the bicycle to work properly such as physical integrity.

2.2 Affect Expression

A popular saying goes "Communication is the base of any type of relationship", and by experience we know that communication between human beings does not only rely on verbal skills but also in body gestures. All of these components are influenced by situations, needs, goals and personality [12] of the agent. Hence the need to attribute affect expressions to machines -whether they are humanoid, iconic or abstract expressions- to enhance human-machine interaction. The use of affect expressions have been studied and applied to different projects[10][12][16], and one of the main goals besides the improvement of communication is to induce affective effects in the observer.

This study is based in the use of abstract expression of affect in order to synthesize the expressions of a bicycle. Abstract expressions attempt to use minimal reference to the human body through the use of simplified shapes, colors and movements and based on the abstraction of perception[2]. The goal is to use only the minimal necessary characteristics to convey emotion expressions. Rooij *et al.* argue that this approach could facilitate the expression of affect in robots by maximizing the possibilities in their technological requirements.

2.3 On the road

The use of Affective Computing systems on the road is a topic that is increasingly being studied and applied partly because of the market success that it may represent, but mostly because of the safety and comfort improvements that it will provide [1][16]. States such as fatigue, stress and nervousness might be detected and because of the effect that these emotions have on the abilities of the driver it becomes necessary to develop ways of prevent and/or correct them. Multi modalities recognizers -used to detect the affective state of the driver- increase the effectiveness of emotion recognition by analyzing constant feedback from the driver to the car. Then, this information can be use to generate the most optimal response from the car to the driver. Hence, this interaction could allow a car to become a social companion improving human-machine communication [1] [17].

In the line of safety and transportation some projects have been developed, those include speech recognition systems [18][19][20], stress detectors[11], recognizing drivers' affective states by physiological data signals[21][22][23], etc. but basically most of the projects on Affective Computing in transportation focus on the emotional state of the driver and generating feedback that will help the driver.

One example is AIDA[17] (Affective Intelligent Driving Agent), project developed at MIT that aims to provide a driving companion able to perform several tasks, as learn the common destinations used by the driver, advise on the best possible routes, be a centralized source of information and monitor the state of the car (e.g. if fuel is required). The system obtains information from a set of sensors like a microphone, camera, galvanic skin response reader, accelerometer, fuel gauge, braking pressure, among others. AIDA aims to become another car passenger, that supports the driver (AIDA is not the car) and this is one of the main differences with our project, where SEB, the bicycle itself, is the companion of the rider. Another relevant difference is that for this study we are mainly focusing on the possibility to create a human-bicycle bond by the use of abstract expressions of affect and the interpretation that people give to them. Hence, we are not measuring the immediate affective state of the rider and the rider's response to the bike's manifestation.

2.4 Smart Bicycles?

The MindRider, for example, is a bicycle helmet that translates electroencephalogram (EEG) feedback into an embedded LED display showing green lights when the state of the rider is focused, red lights indicate anxiety, drowsiness and flashing red lights indicate panic. This with the purpose to increase safety and awareness of the cyclist state [5]. And there lies the main difference with this project, because it reflects the emotional state of the rider, not the state of the bike. However, the representation of the affect is done with the use of colors and movements of the lights -as in an abstract expression- instead of making references to human-like representation.

An interesting case that is based on a bicycle itself is *Precious*, a bike with a brain, that was built as part of a project by Janeen McCrae where she rode the bike across the United Stated to raise money in benefit of LIVESTRONG[7]. The brain of the bike was built by the company Breakfast and it consists of a series of sensors that measure temperature, humidity, grade, speed, cadence (pedal rotation), direction and GPS. These values were then sent to a server that maps them into messages that were tweeted. The author of the messages was the rider McCrae, who on her own words by doing this "created the personality of Precious". Here can be found the main differences with this project. The author, by writing how the bike feels, is the shaper of the personality of the bike. Because the feedback from the bike is through automatic tweets, the rider is not able to see such response immediately or at least from the found literature it is unclear whether this is possible, furthermore, because she is riding the bike it is possible to assume that the rider cannot check her Twitter feed at the same time as riding the bike. It is also unclear if this interaction created a bond between the bicycle and the rider. However, the amount of followers on Twitter that Precious has - 1775 by July 2013- suggests that people might be interested in knowing the state of the bike and the development of this character through the journey.

2.5 Affectional bond

According to Bowlby[14] an affectional bond is the attraction that one individual has for another individual. Bonds develop when an individual realizes that in order to reduce a drive or need another object -that can be a material object or a living being- is necessary[25]. Bowlby's Attachment Theory is explained as the tendency of human beings to make a strong affectional bond to others. This type of connection can easily be found in the way people might respond to a particular object e.g. feeling confident in a sports car, safe at home, buying only products from a particular brand, distress from separation from an object, etc. Marketing studies explore this concept for evaluating fidelity to brands [26], attachment to products[28], among other topics related to consumer behavior[27].

3. SEB, the Bike

A horse is a companion and at the same time it is a transportation mean, we want our bike to be the same. By using the metaphor of a horse to visualize SEB as a living being, it is feasible to apply a Homeostasis approach to model an affect state with the use of a dimensional model. This will give the possibility to define an artificial personality for the bicycle.

3.1 Personalities

Considering that horses and other animals can have personalities with characteristics that are inherited, linked to fitness and vary from one subject to another[24], by following our metaphor of the horse, bicycles could be seen as having projected personalities which had been designed taking into consideration the type and individual characteristics of the bicycle. From a previous study at the Affective Computing course at TUDelft[32] the following types and artificial personalities were considered:

- Mountain bike: It is always ready for an adventure, bumping roads and the contact with rocks and plants. This bike does not care much about the weather or getting dirty.
- Race bike: likes speed and has to be very well maintained to perform properly.
- Grandma bike (The typical Dutch bike): It has very limited functionality, no gears, only pedal breaks, goes slowly and safe, can carry some groceries but does not appreciate being overloaded.
- Student bike: It only needs enough speed to get on time to class. Just as a student it lives on low budget so it needs to be properly locked and safe.
- Family bike: safety is a priority, it is strong enough to carry more than one person, as a matter of fact it feels that it is completing its purpose when it can carry more than one person.
- Kids bike: it is small but strong enough to survive falls but it is afraid of dark places and prefers to go slowly.

Therefore, the personality of the bike is defined by the balance point of the needs and drives that characterize a bicycle. Given the characteristics of the bicycle available for this study, SEB will be modeled as a student bike. In order to model a more individual personality, particular characteristic have been chosen for SEB e.g. SEB does not like cold weather.

3.2 How SEB feels

In order to design an affect state for SEB, a model with four main scopes is used: Sensor Space, Need Space, Emotion Space and Expression Space, *Image 1* show the relation among them.

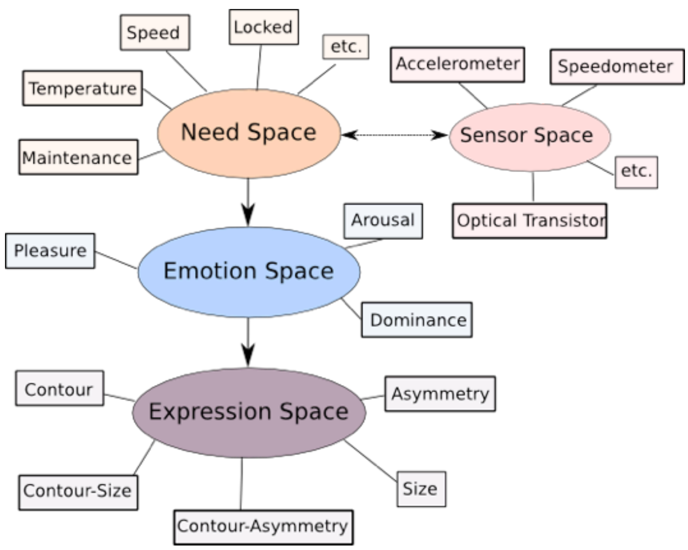

Image 1

The Sensor Space refers to all the values collected from the sensors placed in the bicycle. The Need

Spaces alludes to the possible needs that a bicycle might have based on its so-called personality, and their achievement will be evaluated by the measurements obtained from the sensors. The Emotion Space describes the emotions -in a three dimensional representation- produced from the fulfillment of the aforementioned needs or lack thereof. Finally, the Expression Space relates to the graphical representation of the resulting emotions based on previous research on Abstract Affective Expressions[3] and more deeply discussed in section *3.3 Showing SEB's Affect State***.**

From the aforementioned study [32] it was also identified the needs of a bicycle shown in *Table 1*. The study was a first attempt to explore the incorporation of an affective system in a bicycle. The needs identified as the ones that a bicycle could have in order to synthesize its emotions have been categorized as:

•Physical Integrity: The need to be in optimal physical conditions.

•Usefulness: The need to fulfill its purpose, this has been divided into: Load, Flow and Speed.

•Relationship: The need to be cared by/connected to its owner.

•Energy: The need of kinetic energy input.

Needs		Variables
Physical Integrity		Damage (avoid)
		Overload (avoid)
		Fitness
		Temperature
		Shelter
		Road conditions
		Maintenance
Energy		Kinetic energy input
Usefulness	Load	Weight
	Flow	Balance
		Ascend/Descend
	Speed	Speed
Relationship		Maintenance
		Contact-Attention
		Locked
		Light/Darkness
		Shelter

Table 1
Identified Needs of a Bicycle and possible variables used to measure the fulfillment of the given need

After analyzing possible ways of getting the required data to measure the state of these needs, and the viability to build the required hardware, the final set of needs to be used were narrowed down. Hence, the present study does not include the need "Energy".

A selection of sensors were used to detect the state of the bike and from that formulate its affect state. Then, an LCD screen is used to present this state to the rider through images. The selected hardware is discussed bellow. The disposition of the sensors can be seen in *Image 2*.

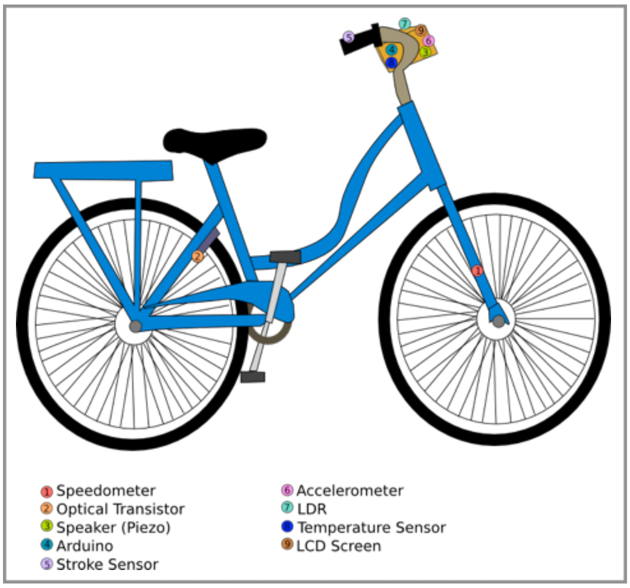

Image 2

3.2.1 Input Sensors

Electronic sensors are used to take measurements from a certain situation or an event that SEB experiences. *Table 3* lists the sensors that have been used for each variable related to the needs of the bicycle.

Variables	Sensor
Damage (avoid fall)	Accelerometer
Temperature	Temperature sensor
Shelter	LDR and Temperature/Humidity sensor
Road conditions	Accelerometer
Maintenance	Self assessment button
Balance	Accelerometer
Ascend/Descend	Accelerometer
Speed	Speedometer
Light/Darkness	LDR
Contact	Stroke sensor
Locked	Speedometer and Optical Transistor

Table 3

3.2.2 Output Devices

A primordial objective of synthesizing emotions is to present them to the user, in this case to the rider, *Table 4* shows the devices used for the affect expression.

Device	Description
LCD Screen	Generated images based on the PAD values and [30]
Piezo Speaker	Sounds that indicate a significant change of affect.

Table 4

A complete diagram of the circuit built for SEB can be seen in *Image 3*.

3.2.3 Needs and Affect

Each change in need is mapped to a PA value that are dependent on that need. As the measured value moves away from the desired point, because it is either overwhelmed or under-stimulated, the resulting affect becomes the one indicated in the column *Affect on no Homeostasis* on *Table 5*, while the *Affect on Homeostasis* column shows the resulting affect when the value is near the desired point.

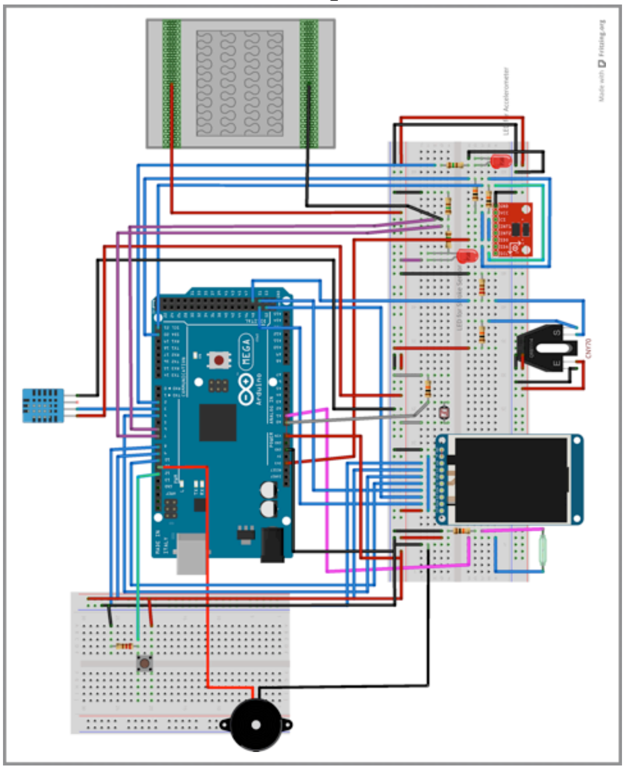

Image 3

Need	Affect on Homeostasis	Affect on no Homeostasis
Physical Integrity	Serenity, Joy	Annoyance, Fear, Anger
Flow	Joy	Fear
Speed	Happy	Fear (too fast) Annoyance (too slow)
Relationship	Serenity, Joy, Trust	Fear, Sad

Table 5
Possible affect states of the Bicycle while on Homeostasis (Sensor values near the optimal point) or not on Homeostasis (Sensor values far from optimal point)

Following a Dimensional Theory [13] for classification of emotions, the identified affect state can be transferred to a Pleasure and Arousal space. Hence, the dimensions increase or decrease as the homeostasis value gets closer to the optimal value or closer to zero (in the need's defined scale). The *Image 4* shows the dynamics of each dimension for each need. e.g. if the bicycle is going faster than the optimal speed, this will result in a negative pleasure and a positive arousal, when the speed approaches the optimal level, the value of pleasure will increase and the value of arousal will decrease. Therefore, if the stimulus is too high the drive becomes overwhelmed, if it is too low it becomes under-stimulated[31].

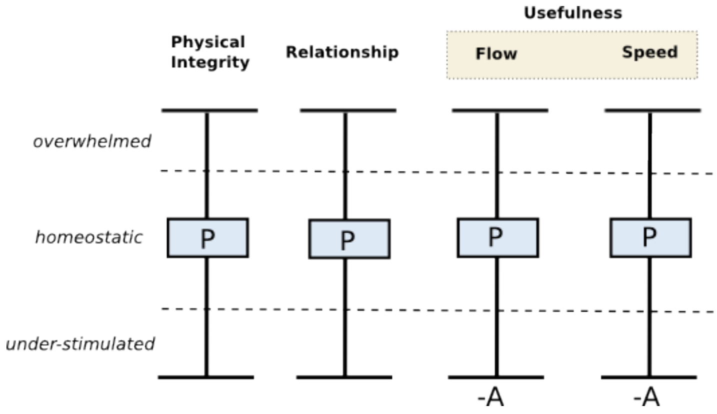

Image 4
Relation between needs and the PA dimensions. The blue squares represent the preferred state (Homeostatic). The PA dimensions attached to the preferred state decrease or increase according to its `proximity to the preferred state. The PA dimensions listed below the need range indicate their mapping to the overall range of the need. The symbol - indicates an inverse relation.

The values of the dimensions are separately measured by each of the needs, having all of them the same weight in the final value. The dimension related to the preferred state will have a maximum value of 1 depending on its proximity to the desired point and a minimum value of -1 when further away from the desire point. The dimensions mapped to the overall range of the need have a minimum value of -1 and a maximum value of 1. Furthermore, the value defined for the desired point will allow us to define the personality of the bicycle e.g. in the case of the need of Relationship, if the optimal point is high (in a predefined scale) this could result in a "pampered" bicycle while a low optimal point could result in a more "independent" bike personality. Table 6 shows the range values and the optimal value of the stimuli that a bicycle can receive for each need.

Need	Min. Value	Max. Value	Optimal Value
Physical Integrity	0	10	7
Flow	0	4	2.5
Speed	0	40	15
Relationship	0	10	5.5

Table 6
Minimum, Maximum and Optimal Value for the Stimulus that the bicycle receives. Different personalities of bicycles can be modeled by modifing the optimal value.

For example, in the case of relationship the stimuli that a bicycle receives is shown in Table 7. These emotion elicitors are computed in order to obtain a value that will be mapped into a PA scale. The rest of the needs are explained in the Appendix I.

Variable	Action	Effect
Maintenance	Press the button	+ 2
Contact-Attention	Touch the stroke sensor	+ 0.25
Locked	Lock the bike	+ 2
Light/Darkness	light of the environment (outside/inside)	+ 0.0001

Table 7
Values computed for the stimuli received in the case of the need Relationship. '+' value added

3.3 Showing SEB's Affect State

Previous Abstract Expressions research [30][2] provides guidelines to consider when designing the representation of SEB's affect state. [30] shows that certain combinations of geometric features can elicit affect, Table 8 shows a summary from the previously mentioned study with this relation and applied for this model.

		Factor		
Feature		Pleasure	Arousal	Dominance
Contour		+ + + rounded contour (pleasure) and - - - angular contour (displeasure)		
Asymmetry		-	- -	-
	Rot.		+ +	+

	Factor		
Feature	**Pleasure**	**Arousal**	**Dominance**
Size		+ +	+

Table 8
'+' Positive relation, '-' Negative relation. Amount of +,- symbols represent the relevance

Image 5 show possible geometric shapes as result of the change of the PA Dimensions.

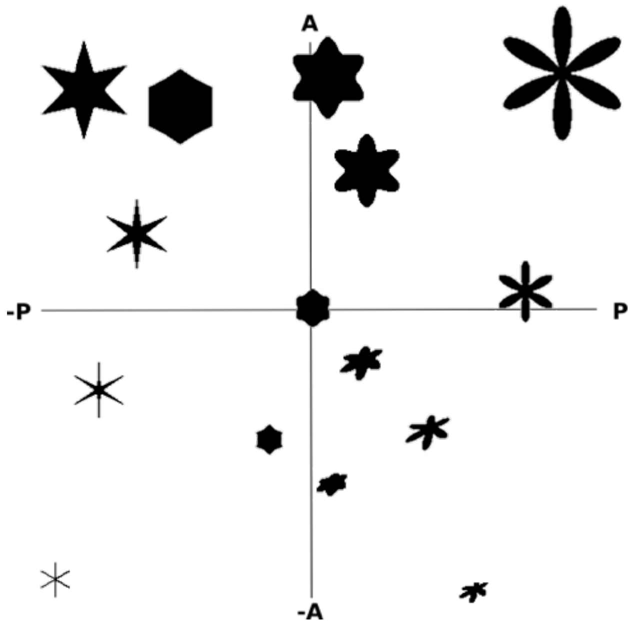

Image 5
Changes in Pleasure (P), Arousal (A) and Dominance (D)

A simulation system of the model was written in Prototype and the final implementation was made with Arduino using C++. *Image 6* shows SEB, the final prototype used for the testing.

Image 6 SEB

4. Getting to know SEB

The tests for this research were carried out in two stages: one static scenario and one interactive scenario. The static study scenario was an evaluation on the algorithm that generates the shapes that were to represent the synthetic emotions of SEB. The second stage was a study of the interaction of the participants with SEB during one day.

4.1 Static evaluation

For the first part of the study two experts on Abstract Expression of Emotions (Alwin de Rooij and Joost Broekens) were given twenty images generated by our model explained in the previous sections. The study was initially intended to use PAD (Pleasure, Arousal and Dominance - Mehrabian[13] three factor theory) the objective of this first test was to evaluate if this was the right approach for the model. In order to accomplish this, the experts were to evaluate each image and give a PAD value for each of them. Afterwards a correlation was calculated between the values used to generate the images and the values assigned by each of the experts.

4.2 Interactive evaluation

For the second part of the study, participants were able to test the bicycle for one day in which they performed all their normal activities as if it were their own bicycle. There were two questionnaires, one for before and one for after the test. Besides this, users were asked to fill in a form with remarks about events that might have occurred during the test, finally, comments made to the researcher were also recorded. The first questionnaire gathered information about each participant such as age, gender, familiarity with bicycles, etc.

The second questionnaire contained questions to measure Social Presence, Perceived Enjoyment and Intention to Use[33], measure product attachment, product personality dimensions[34] and finally it incorporated statements from the Godspeed Questionnaire[35], the objective of all this questions is to analyze how participants perceived the bicycle after using it. The complete questionnaires can be found in the appendix II.

Image 7
User interacting with SEB

When given the bicycle, the participants were explained how to take care of it, e.i. mount and dismount the “brain” of the bike. And the basic meaning of the representation of the emotions e.i. angular shapes are negative emotions, rounded shapes are positive emotions, and size represents the intensity.

5. Results

The results for both evaluations are explained below.

5.1 Static evaluation

The results of the first test showed that the perception of Pleasure towards rounded and angular images is more clear than the perception of Arousal and Dominance. Furthermore, the perception of Dominance is the least clear of all. One reason could be that both dimensions have impact on size and asymmetry, hence it makes it more difficult to identify which dimension is the predominant in a given shape. *Table 9* show the correlation values obtained.

Dimension	C1	C2	C3
P	0.74	0.8	0.71
A	0.757	0.1	0.48
D	0.04	0.25	0.71

Table 9
C1: correlation between Expert1 and System, C2: correlation between Expert2 and System, C3: correlation between Expert1 and Expert2

After analyzing these results it was decided to drop Dominance from the model and continue with P and A. After all, in the case of the bike, and as the next section shows, it can suffice to distinguish if SEB is having positive or negative emotions and their intensity.

5.2 Interactive evaluation

For the second part of the study seven participants where gathered, three males and four females, each of them had the bicycle under their care for approximately 24 hours, the actual time of use varied from 20 mins to 1 hour. There was an unexpected hardware failure while participant #5 was testing the bicycle therefore her results were not considered for the analysis. The participants have different nationalities and come from different professional backgrounds, some related to biology, technology and law. The age range of the participants is from 20 to 31 years old and all of them have over two years of experience riding bicycles.

The core aspects of the research is to determine whether people can understand what are the emotions of the bicycle, relate to them and develop an emotional bond. To find the answers to these questions we proceeded to analyze each experience. We were particularly interested in how people viewed SEB and its emotions, the personality traits attributed and how connected they felt with SEB.

For the first part, participants agreed that more time and information was required in order to more effectively understand what triggered SEB’s emotions, for example user #4 expressed that after some attempts and while trying different things he was unable to understand why SEB was still not happy. One user attributed the use of the dynamo to have an effected on the emotions, what was really happening is that the dynamo makes the bike slow down because of the friction that is exerted on the wheel. Therefore, the bicycle was going at a lower speed, closer to the optimal value. On the other hand, user #1 noted that riding in sunny parts of the street changed the shape into less angular, making her feel that the bike was happy and liked sunlight. And most users noted that petting the bike made it happier, both were correct interpretations. Hence some stimuli were more clear than others.

However, despite the difficulty to detect exactly what made SEB feel one way or the other, participants were still able to assign personality attributes to the bike. The personality traits more highly evaluated were gentile, energetic, honest, stable, flexible and rebellious. Also, while two participants found it simple, four found it somehow complex. One participant felt it should have a girl's name, others though that a more appropriate name could be Mystery, Robota or e-bike.

Finally, when asked on their connection to SEB, most participants felt that SEB was really communicating with them. However, the participants that found more difficulties while trying to understand the needs of the bicycle felt less connected to SEB. Which shows the importance of the context when trying to create bonds. And most agree that more time was required to improve that understanding.

During the interview, after the experiment, a further explanation on the sensors used in the bike helped participants understand more of the triggers of the emotions, for example why going on a bumpy road, too fast or during the night was making the bike have a negative emotion. Perhaps it could have helped the users to have this information before hand, however, a more detailed information was not provided purposely in order to allow the participant to discover what actions affect the bike during the interaction.

Another interesting remark is that even though the Stroke Sensor does not interfere with the actual physical functionality of a bicycle, it showed to be one of the clearest ways to interact with it and to understand its response by means of changes of the representation of affect. Participants commented the comfort they felt while "petting" the bike by stroking the sensor and as one of them mentioned, she appreciated having it, it made them feel more connected.

All in all, participants were pleased by the experience. They found SEB interesting, enjoyable and fascinating.

6. Conclusions and Discussion

Although a bigger amount of users and a longer amount of interaction with the bicycle could have been better, these results show first of all that it is feasible to create a bond by understanding the needs of a bicycle and a prolonged interaction with it. Second of all, that the use of Abstract Expressions of Affect, although might be no very familiar to start with, can certainly be a mean to communicate the emotions of the bicycle.

Extended time of interaction is required to understand more accurately what actions trigger what emotions. One reason why it was not easy for all participants to understand SEB could be the complexity of the system and the amount of stimulus the bike was subjected to. This could be simplified in order to keep the most relevant variables and have a better realtime response in order to have a behavior with resonance in humans.

Overall, the information gathered from this evaluation suggest that participants did not have major issues understanding the shapes presented (one exception could be the asymmetrical shapes), nor they expected or asked for another way of feedback. Although users were not always sure why SEB was having an specific emotion, they were able to identify how the bicycle was feeling, which shows that indeed the use of abstract shapes is a viable way of representing emotions.

7. Future work

It is also worth mentioning that a novelty factor could also be responsible for igniting the interest on a project like this. But that can be the starting point for exploring applications for an emotional bicycle and its consequences.

Other questions have arise during this project. Some interesting ones are: are there benefits of feeling emotionally connected to your bicycle? and would this method be more efficient than other types of expression of affect more well known?

For the first question, maybe people will start taking better care of their bicycles if they see them as a companion more than an object. Perhaps for others it could be an incentive to exercise more, e.i. applications in the exergaming area could be developed, or in other countries where bicycles are not such a popular mode of transportation this could help increase the interest in such alternative. Also the bike's personalities could be customized given the users a more suitable experience.

The second question requires a deeper comparative study with more users and more time, with the challenge that novel methods are much less known than popular ones but it could be an interesting research nonetheless.

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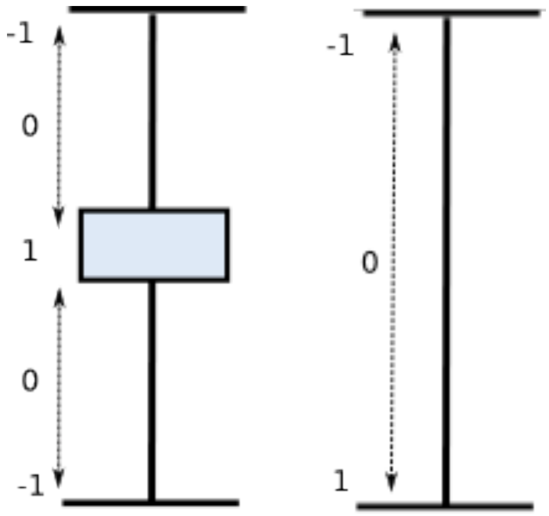
Appendix I

For all the needs, the resulting value is converted to a scale between -1 and 1. The dimensions that are attached to the preferred state will tend to 1 when closer to the optimal value, for the other dimensions they are directly mapped following the definition made in section 3.2.3



'+' value added

'-' value subtracted

Need Relationship:

Variable	Action	Effect	No action
Maintenance	Press the button	+ 2	-0.00001
Contact-Attention	Touch the stroke sensor	+ 0.25	-0.0001
Locked	Lock the bike	+ 2	-0.001
Light/ Darkness	light of the environment (outside/ inside)	+ 0.0001	-0.001

Need Physical Integrity:

Variable	Action	Effect	No action
Damage	Fall	-2	+ 0.0001
Temperature	Comparison with optimal value	+ 0.001	-0.001
Road Condition	Bumps	-0.01	+ 0.0001
Shelter	Speed = 0, bike is locked and light is low (is in storage room)	+ 2	-0.001
Maintenance	Press the button	+ 2	-0.00001

Need Flow:

Variable	Action	Effect	No action
Balance	Variations on X angle and Y angle	-0.001	-0.001
Ascend/ Descend	Variations (absolute value) on Y angle higher than 60	-0.001	+0.0001

Need Speed:

In the case of speed, because this need requires only one variable, the actual speed of the bicycle (KPH) is mapped into a value between -1 and 1, where 1 equals the optimal value for speed in the case of the dimension Pleasure. In the case of the dimension Arousal the speed is inversely proportional mapped to the same scale.

Possible scenarios of stimuli analyzed:

Variable	Optimal State	Worst scenario
Damage (avoid fall)	Stable value in vertical position within a threshold	Drastic change of the vertical position, i.e. the bicycle falls
Temperature	Temperature near 10ºC	Temperature less than 5ºC

Variable	Optimal State	Worst scenario
Shelter	No light	Bike has been left outside
Road conditions	Little changes on vertical position	Going through a bumpy road
Maintenance	Regular check up	No check up
Balance	Stable value in vertical and horizontal position	Constant changes in the X and Y angles
Ascend/Descend	Avoid steep hills	Crossing steep hills
Speed	Speed around 15km/h	More or less speed than 15km/h
Light/Darkness	Bike is being used during the day	Bike is being used during the night
Contact	Proximity of the rider	Bicycle is not being used
Locked	While not in movement the bicycle is properly locked	Bicycle is left unlocked

Appendix II

Participant Number __________

Informed Consent Form

Media Technology
LIACS
Leiden University

Title of Project:	S.E.B. - Synthetic Emotions Bicycle
Principal Researcher:	Tamara Pinos Cisneros tvpinos@gmail.com 06-38004382
Advisors:	Maarten Lamers, Leiden University Joost Broekens, TU Delft

The purpose of the study is to analyze the interaction between a person and a bicycle that shows emotions and the possible effects of such interaction. You will be asked to use the provided bicycle during one day and record significant events in the questionnaire supplied. You will also be asked to fill in a survey before and after the testing.

Your participation is voluntary. Refusal to participate or withdrawal of your consent or discontinued participation in the study will not result in any penalty. The principal investigator may at her discretion remover you from the study for any of a number of reasons. In such an event, you will not suffer any penalty either.

Your anonymity will be maintained during data analysis and publication/presentation of results by any or all of the following means: (1)You will be assigned a number as names will not be recorded. (2) The researchers will save the data file by your number, not by name. (3) Only members of the research group will view collected data in detail. (4) Any recordings or files will be stored in a secured location accessed only by authorized researchers. Photographies regarding the use of the bicycle might be used for presentation purposes.

If you have any questions about this study, you should feel free to ask them now or anytime throughout the study by contacting: Tamara Pinos C., Master student, Leiden University, E-mail: tvpinos@gmail.com, Phone: 0638004382

I understand the nature of this study and agree to participate. I received a copy of this form. I give the principal investigator and her associates permission to present this work in written and/or oral form for teaching or presentation to advance the knowledge of science and/or academic without further permission from me provided that my name or identity is not disclosed.

Please sign below if you understand this information and voluntarily agree to participate.

______________________________ ______________________________
Participant Signature Date and place

Participant Number __________

S.E.B. - Synthetic Emotions Bicycle

Questionnaire

Thank you for participating in this research, all the information provided below will only be used for research purposes. Please answer the following questions.

<u>Participants Information:</u>

Gender: M ( ) F( )

Age: _______

Nationality: _______________

Start time of the experiment: _____________

<u>Participants use of bicycles:</u>

1.**Do you own a bicycle?** Yes ( ) No ( )

2.**For how long have you been using a bicycle?** __________ (years) (months) (days)

3.**How often do you use a bicycle?** *(Circle the appropriate answer)*

Never Rarely Sometimes Often Always

4.**Do you give a name to your bicycle?** Yes ( ) No ( ) **If yes , what is the name?** _________________

5.**Do you own more than one bicycle?** Yes ( ) No ( ) **If yes, how many bicycles do you own?** _______

6.**How many bicycles have you owned in the last year?** ______________

7.How often do you do maintenance of your bicycle? *(Circle the appropriate answer)*

Never( ) Once a Month ( ) Once a week ( ) Several times a week ( ) Everyday ( )

8.How would you describe the condition of your bicycle?

Very poor Poor Fair Good Excellent

Participant Number ___________

S.E.B. - Synthetic Emotions Bicycle

Questionnaire

Finish time of the experiment: ______________

Please answer the following question after the experiment is finished.

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think I'll use SEB again					
2. I think SEB is useful to me					
3.I think I will know quickly how to understand SEB					
4. I find SEB enjoyable					
5. I find SEB fascinating					
6. I find SEB annoying					
7. I find SEB boring					
8. It sometimes felt as if SEB was really communicating with me					
9. I think I understood how SEB feels					
10. I can imagine SEB to be a living creature					
11. Sometimes SEB seems to have real feelings					
12. SEB is very dear to me					
13. I think I understood what SEB likes					
14. I have a bond with SEB					
15. SEB has no special meaning to me					

Participant Number ___________

Please rate your impression of the robot on these scales:

Stagnant — Lively

1	2	3	4	5

Inert — Interactive

1	2	3	4	5

Apathetic — Responsive

1	2	3	4	5

Dislike — Like

1	2	3	4	5

Unpleasant — Pleasant

1	2	3	4	5

Please rate your emotional state on these scales:

Anxious — Relaxed

1	2	3	4	5

Calm — Agitated

1	2	3	4	5

Quiescent — Surprised

1	2	3	4	5

If I could change the name of the bicycle, it would be _________________

Select the Personality traits that could be attributed to SEB:

1	kind	somewhat kind	neither kind or unkind	somewhat unkind	unkind
2	honest	somewhat hones	neither hones or dishonest	somewhat dishonest	dishonest
4	bright	somewhat bright	neither bright or dim	somewhat dim	dim
5	stable	somewhat stable	neither stable or unstable	somewhat unstable	unstable
7	flexible	somewhat flexible	neither flexible or inflexible	somewhat inflexible	inflexible
8	authoritarian	somewhat authoritarian	neither authoritarian or liberal	somewhat liberal	liberal
12	excessive	somewhat excessive	neither excessive or moderate	somewhat moderate	moderate
13	conforming	somewhat conforming	neither conforming or rebellious	somewhat rebellious	rebellious
14	energetic	somewhat energetic	neither energetic or non energetic	somewhat non energetic	non energetic
15	violent	somewhat violent	neither violent or gentile	somewhat gentile	gentile
16	complex	somewhat complex	neither complex or simple	somewhat simple	simple
17	optimist	somewhat optimist	somewhat pessimist	pessimist	

Participant Number ___________

S.E.B. - Synthetic Emotions Bicycle

Record of Events

Please write down any significant event that your might have observed while using SEB.