# REPLICATING THE EMOTIONS OF A FACIAL EXPRESSION ON A FURHAT ROBOT FACE USING A KINECT INPUT.

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# Abstract

Facial expressions reflects a person's emotions or are used socially to express oneself. With the use of a Kinect it is possible to capture 3D points from a face. If the person Bob, who is in front of the Kinect, does a facial expression when data are being caught that data can be used as calibration for that facial expression. Then the same facial expressions are defined for the 3D face application Furhat, making it possible to do a mapping between Bob's facial expression and that of the Furhat. The mapping is done by comparing the length of vectors between some Key Points from Bob's face to the calibration data enabling expression identification and the receival of a percentage of how well the expressions matched. This percentage was multiplied with each Furhat value for that expression to scale the expressions against each other.

With this mapping between the facial expressions of Bob to the Furhat 3D model, a survey were done of how well the emotions of facial expressions were replicated. Pictures taken with the RGB camera of the Kinect were compared to pictures of the Furhat when these pictures were taken simultaneously making both pictures do the same facial expression. The survey were done where the responders assignment were to to write in free text what emotion the facial expression on the different pictures had. The number of respondents was 31. The result for the different facial expressions varied considerably.

The best match between the Furhat and Bob according to the respondents had an accuracy of 61% which is good. On the other hand, the worse matches had an accuracy of less than 20%. Thereof the conclusion that the essence of the facial expressions were not replicated well with the constraints that the mapping together with the Furhat gave.



# Sammanfattning

Ansiktsuttryck reflekterar oftast en persons känslor eller används socialt för att uttrycka sig. Med hjälp av en Kinect kan man fånga 3D punkter från ansiktet. Om personen Bob, som är framför Kinect:en, gör ansiktsuttryck medan data fångas så kan den datan användas som kalibrering för dessa ansiktsuttryck. Sedan definieras samma ansiktsuttryck i 3D-ansiktesappliationen Furhat, då går det att göra en mappning mellan Bobs ansiktsuttryck och Furhat:ens ansiktsuttryck. Denna mappning görs genom att jämföra längden på vektorer mellan några nyckelpunkter i Bobs ansikte mot den kalibrerade datan för att identifiera vilket uttryck Bob gör samt att få en procentsats om hur väl de stämde överens. Procentsatsen multiplicerades med värdet på varje Furhat parameter för det identifierade ansiktsuttrycket för att skala uttrycken mellan varandra.

Med denna mappning från ansiktsuttryck hos Bob till 3D modellen Furhat så gjordes en undersökning hur väl känslor i ansiktsuttryck speglades. Bilder tagna med Kinect kameran jämfördes med bilder från Furhat:en och dessa bilder togs samtidigt så att de visade samma ansiktsuttryck. Undersökningen som gjordes var en enkätundersökning där deltagarna skulle skriva fritext vilken känsla ansiktsuttrycket på de olika bilderna hade. Antalet respondenter var 31. Resultatet för de olika ansiktsuttrycken varierade kraftigt.

Den matchning mellan Furhat och Bob som blev bäst enligt respondenterna hade en träffsäkerhet på 61 %. Dock så hade de sämre matchningarna en träffsäkerhet på under 20%. Därav drog vi slutsatsen att själen av ansiktsuttrycken inte återspeglades särskilts väl med de begränsningar som mappningen tillsammans med Furhat:en gav.

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# Introduction

Communication is something that almost all animals do. Dogs wag their tail to express happiness, cats purr when petted and apes can laugh when happy or tickled.[1] Humans form words, pitch our voices and use our bodies and faces to express ourselves. When talking to someone in person, you can identify that person by seeing that person, how that person uses the body and facial language, the voice and the actual words.[2] Speaking over a traditional telephone only the audio communication is possible hindering the communication coming from facial expressions.

With the technology of today, it is possible to send both video data from a camera and sound over distances and it is fairly common. Something a little more uncommon is sending data to a physical face that replicates the face of another person while that person is talking which could provide the illusion of an in person meeting.[3] However, seeing a face is only using one sense. With the use of different technologies it is possible for a person to give the impression to be in another location than the actual location of that person and at the same time allow that person to get the impression that he is at this remote location. This is called telepresence.[4] The primary senses that telepresence researchers are trying to stimulate is sight, hearing and touch.[18,19,20,21,22,]

This project is about researching what the best way to map input from *Kinect* to the 3D model Furhat provided by the Speech, Music and Hearing department at KTH. The research is going to be made by having a *Face Actor* stationed in front of the *Kinect*. The Kinect will start collecting data about the person's facial expression, running it through our mapping process and lastly sending it to the 3D modeling program that makes the expression.

## Problem statement

In this project the problem statement that will be discussed is:
*Given an emotional face expression, how well can the animated Furhat robot face replicate that emotion with Xbox 360 Kinect input data from that face?*

## Restriction

In this thesis, only some of Ekman's simple emotions[5] are going to be mapped. The emotions that will be mapped are: Joy, Anger, Sadness and Surprise.

## Terminology

*Calibration* - Using known entity (e.g. facial expression) and declare for some unknown entity (e.g. Kinect Face Tracking coordinates) the current state of that known entity. Now that unknown entity has a reference to a known state and can now transition between other known states.
Depth Sensor - A sensor able to determine the distance to various objects.
*Face Actor* - Person who is using the face as input, using some device to do this.
Face Tracking - Process of tracking a person's head position and facial expression.
Furhat - Is our animated face that was provided by The Speech, Music and Hearing department at KTH.
Key Points - The Key Points are defined by the data found in Appendix C.2 - Key Points
Kinect - A sensor with an RGB camera, a depth sensor and an array of microphones.
Mapping - A transformation from a set of data to another.
RGB Camera - A video streaming camera with color capabilities.

# Background

In this chapter context and insight for this project is provided by mentioning research relevant to this project.

## Facial expression

Facial expressions are created through a series of muscular contractions in the face. Some of the facial expressions have a corresponding emotional. Emotions expressed through facial expressions are only using one of the five human senses, the sense of sight[6]. In 1872 Darwin presented his book "The Expressions of the Emotions in Man and Animals"[1] and in this work a hypothesis about universal recognition of a set of emotions was created disregarding any cultural differences. Paul Ekman embraced this hypothesis and defined his first set of emotions to be: Joy, Surprise, Fear, Anger, Disgust and Sadness[5]. James Russell is questioning the method in the studies done by those who embrace this hypothesis, including Ekman's studies[8]. New studies have also strengthened the disbelief on the hypothesis and these new studies show that the subjects cultural background matter[6].

## Kinect

Xbox 360 Kinect is an input device with a depth sensor, a RBG camera and an array of microphones that delivers depth data, RGB data and sound data. Since Kinect SDK 1.5 there has been a Face Tracking Toolkit that uses the depth data in combination with the RGB data to identify 3D points on the head, mainly the face[13]. The Kinect SDK 1.7 Face Tracking Toolkit returns 121 3D points on the face to the application from the Kinect[14]. These 3D points are noisy[17] and should be filtered before use[15].

## Furhat

Furhat is a name for the program that has been partly implemented by The Speech, Music and Hearing department at KTH. The program itself creates a 3D animated human face that can be projected on a mechanical face[9].

**Figure 1: 3D animated face from the Furhat.**

In figure 1 can we see the animated face from the front. Using a bit of interaction with the program, you can create emotions and other facial movements in real time.[9] Thought the Furhat has limitations in its implementation and can therefore only do special predefined changes to the face namely 16 parameters that can be altered in the range of an Java double. These 16 parameters and what they change in the animated face seen in Table 1.

**Table 1. This table showes how each of the parameters**

| | |
|---|---|
| protrusion | How much putts lip out or are withdrawn. |
| mth_width | How wide is the right lip. |
| mth_width#2 | How wide is the left lip. |
| Apex | What position is the tongue. |
| lip_round | How lengthy lips are. |
| lip_tight | How tight lips are |
| f_tuck | What angle lips are in |
| brow_raise | What height right eyebrow is. |
| brow_raise#2 | What height left eyebrow is. |
| brow_frown | where the right eyebrow ends in the middle |
| brow_frown#2 | Where the left eyebrow ends in the middle |
| jaw_rotation | How far down the jaw is |
| eyelid | How open is the right eye |
| eyelid#2 | How open left eye is |
| Smile | Where the left corner of the mouth is stationed |
| smile#2 | Where the right corner of the mouth is stationed |

# Previous research

There are many ways to accomplish the task of replicate the expression from a Face Actor to a 3D model. Many modern games use markers on the face of an actor that collect data[10] while other approaches to project an expression to a 3D model include different multi-camera solutions such as the EU-Project BACS FP6- IST-027140[11] or the more commercial Kinect with some custom software[12].

# Method

In this chapter the process of this project is described by first describe the mapping algorithm and then how the survey was done.

## Implementation of mapping algorithm

In this section of this chapter, the details of the mapping algorithm will be described.

### Pre phase

Before implementing the mapping algorithm the facial expressions to implement were defined. The mapping algorithm will map the facial expressions for joy, anger, sadness, surprise and a neutral expression. For each of these five expressions, the definition of the parameters that makes the Furhat expresses that feeling is required. Each facial expression is showed in Table 2. No expression used the apex parameter of the Furhat, the one representing the tongue, because the Kinect Face Tracking Toolkit does not track it. Apex parameter was 0.00 for all expressions.

**Table 2: This table shows the parameters over the Furhat parameters for each expression**.

| | Neutral | Joy | Anger | Sadness | Surprise |
|---|---|---|---|---|---|
| protrusion | 0.00 | 0.08 | -0.11 | 0.29 | 0.22 |
| mth_width | 0.00 | 0.22 | -0.63 | -0.29 | 0.26 |
| mth_with#2 | 0.00 | 0.33 | -0.63 | 0.36 | 0.24 |
| lip_round | 0.00 | 0.18 | 0.49 | -0.26 | -0.05 |
| lip_tight | 0.00 | 0.06 | 1.00 | -0.55 | -0.09 |
| f_tuck | 0.00 | 0.04 | 0.08 | 0.52 | 0.22 |
| brow_raise | 0.00 | 0.06 | -0.28 | -0.07 | 0.07 |
| brow_raise#2 | 0.00 | 0.06 | -0.28 | 0.07 | 0.11 |
| brow_frown | 0.00 | 0.00 | -0.04 | 0.00 | 0.00 |
| brow_frown#2 | 0.00 | 0.00 | -0.11 | 0.00 | 0.03 |
| jaw_rotation | 0.00 | 0.03 | -0.21 | 0.09 | 0.80 |
| eyelid | 0.00 | 0.06 | 0.07 | 0.12 | -0.12 |
| eyelid#2 | 0.00 | -0.03 | 0.07 | 0.09 | -0.20 |
| smile | 0.00 | 0.42 | -0.06 | -0.21 | 0.00 |
| smile#2 | 0.00 | 0.42 | -0.07 | -0.23 | -0.07 |

Key Points (found in Appendix C.2) is the subset of Kinect Points (listed in Appendix C.1) that the mapping algorithm uses to draw vectors (the points that the vectors are between can be found in Appendix C.3)

## Runtime

The runtime begins by searching for a potential Kinect Sensor, if found it will set it up. Kinect setup consists of starting RGB stream, depth stream and skeleton stream as well as allocating data arrays for the Kinect to use. After all of the streams and data arrays are set up the Kinect can be started, the Face Tracker can initialize and the Kinect be ordered to send an event when all sensors have new data ready to be read.

When the event for new data is sent, it will call a function that validates that the data is enough for the Face Tracker by checking the RGB stream, depth stream and skeleton stream for data and that there is in fact a skeleton present on that frame of the skeleton stream. If the data is good it will be sent to the Face Tracker and a face frame is received. That face frame contains the current data, the 121 points, on the face from the Face Actor.

After validating the data and the face frame is received, that data will be placed in a ring buffer. The ring buffer is an array that will always replace the oldest value and in this case have eight snapshots stored at the same time. Using an average of the latest eight frames will smooth the noisy Kinect data or just use the sum of each component of the vector and compare it to another sum from the ring buffer.

To properly identify an expression, the algorithm needs something to compare the data to; calibration is needed. The Face Actor makes each of the five expressions and presses a key on the keyboard when ready, saving the picture provided by the RGB camera at the same time. Vectors between Key Points of the collected data during calibration, the sum of each dimension of the data in the ring buffer that is, will be stored as calibrated version of that expression. Calibrated data will be treated as making the most extreme Furhat expression. Sum of the Kinect data from the ring buffer for the calibrated faces used in this project can be seen in Appendix D.

When the calibration were done the mapping application were connected to the Furhat application using TCP sockets. Parameters to the Furhat will be sent using these sockets.

After everything is set up and the calibration have been done the expression identification process should begin. This process will do the same validation and filtering as the calibration and will create vectors between the same Key Points. The expression showed in Formula1 identification algorithm receives a percentage, $P_e$, of how well the lengths of current vectors, *c*, matches the lengths of vectors for some expression *,e,* by comparing it to the lengths of vectors in the neutral*, n,* expression using the following formula with number of vectors*, V,* amount of vectors.

$$P_e = \frac{\sum_{k=0}^{V-1}\left( max\left( 1-\left|1-\frac{c_k - n_k}{e_k - n_k}\right|, 0\right)\right)}{V-1}$$

**Formula 1: The formula of calculating how well a current expression matches an existing one. I**

**V is the amount of vector length imputed. $c_k$ is the current vector length between two points, $e_k$ is the pre calibrated vector length between the same points and $n_k$ is the ideal normal expression. $P_e$ is the result retuned as percent.**

The purpose of this function is to receive how close the *current* expression is to the *expression*. It should return a number between one and zero, a percentage of how well the expression is matching. By making this for each expression except for the neutral four percentages, one for each expressive expression, have been calculated. Compare each of these four percentages to the max value of the four percentages to get what expression is the most expressive.

Finally take that percentage and multiply it to the values representing the Furhat expression that had the highest percentage. Send the Furhat values to the Furhat using the TCP socket earlier set up.

On a keyboard command, the application would save the next RGB camera frame to file and pause the sending data to the Furhat so it would mirror the facial expression of the Face Actor as good as possible, giving time to save the current Furhat expression to file.

# Survey

## Creating and processing data for the survey

Before the survey can take place, it needs to be created. This survey needs matching pictures of a Furhat and a Face Actor done by a keyboard command in the application. Save seven pictures using the keyboard command to save pictures; remove a Furhat picture and a picture of the Face Actor that does not match each other but are otherwise chosen at random. After removing these two pictures, shuffle the Furhat pictures then shuffle the pictures of the Face Actor. The order of the pictures were noted and always shown in that order. The order and faces is showed in Figure 2.

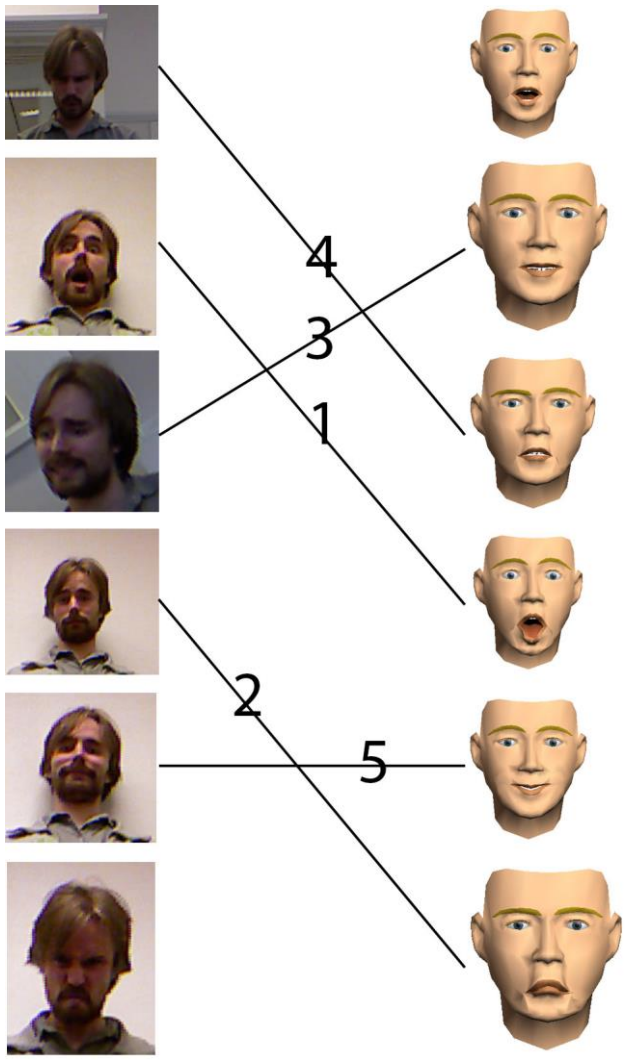


**Figure 1: The six pictures to the left are the once from the Face Actor before the mapping.**

**The six pictures to the right are the once from the Furhat after the mapping. The order of the pictures is from top to bottom**

**The lines in between are the matching pairs and the number is the order they were presented in.**

## Survey

The survey was done in three steps. In the first step the pictures of the Face Actor were shown to the responder one at a time in order and the responder were told to write down in free text what emotion the Face Actors face were expressing on the current picture.

When the responder has written down an answer for each picture in the first step, the second step began. Much like the first step the responders were shown pictures, but now of the Furhat instead of the Face Actor, and were told to write down what emotion the facial expression of the Furhat was showing.

In the final step of the survey, the responder should give a number from one to ten on how well the emotion of the facial expressions matched each other for a Face Actor-Furhat pair of pictures.

## Processions of responses from the survey

In each of the two first steps in the survey, five out of the six pictures shown in that step had a matching picture in the other step. The processing of these two steps were done by checking if both matching pictures had the same expression written on the picture numbers corresponding

to each other. Few synonyms, different tenses or different amount of the same feelings were accepted such as anger and angry, scared and terrified, wicked and murderous. Using the number of correct matches a percentage of how well that expression matches were calculated.

After that percentage was calculated, it is time to process the third step of the survey. Before calculating anything the data has to be validated; the scale were from one to ten meaning any number under one was set to one and any number above ten were set to ten. Answers without numbers were discarded. Other than the validation step the processing of the data to percentages were done by simply taking an average for each pair of pictures and divide by the highest number in the scale, ten.

### Why this type of survey.

Without assuming that the hypothesis about universal recognition is true, it is impossible to define an accurate, universal, facial expression for a given emotion; people could identify emotions differently. With this in mind, we chose to research how well the responders identified the same emotion on the paired pictures instead of having a correct answer for each separate expression.

The reasoning behind step three of the survey was to get an indication on how well the responders could see that the expressions matched.

# Result

There were 31 respondents in this survey. Answers of the survey can be found in Appendix A.1 and the processed data can be found in Appendix A.2.

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**Table 3:** ***Showing percent of correct matches between the pairs seen in Figure 2.***

| | |
|---|---|
| Pair 1 in Figure 2 | 61% |
| Pair 2 in Figure 2 | 10% |
| Pair 3 in Figure 2 | 3% |
| Pair 4 in Figure 2 | 19% |
| Pair 5 in Figure 2 | 45% |

As seen in Table 1, the pair that the most responders successfully matched was that of pair 1 with 61%. Pair 1 was designed as a surprised expression and 61% managed to match the Face Actors expression with that of the Furhat. The second highest accuracy were 45% and it was designed as a happy face. The other three expressions were all under 20% and the lowest matchrate of 3%.

**Table 4:** ***Showing a percentage of how well the respondents thought that the emotion of the facial expressions of the Face Actor were replicated by the Furhat for each pair of pictures found in Figure 2.***

| | |
|---|---|
| Pair 1 in Figure 2 | 81% |
| Pair 2 in Figure 2 | 35% |
| Pair 3 in Figure 2 | 40% |
| Pair 4 in Figure 2 | 51% |
| Pair 5 in Figure 2 | 66% |

As seen in Table 2, the pair that the respondents thought had the best emotional match were that of pair 1 from Figure 2 with 81%. The second best were that of pair 5 with 66%. The other three pairs were within 15% of each other from 35% to 50%.

# Discussion

In this chapter the conclusion is presented by first discussing the result, then the equipment used, then some ways to evolve this project is presented, later the possible sources of error is discussed and finally the conclusion is presented.

## Survey Result

The result in Table 1 shows that two of the matches were almost recognized half of the times as the same expression. Meanwhile the remaining three was not nearly matched at all. To the result it also should be noticed that Figure 5 appendix A.3 has 25% that says Joy-Pleasure which are two very nearly related emotions (see Appendix A).

The result in Table 2 gives indication that Figures 1 and 5 was not spot on but transmitted the same facial expression. From Figure 4 it could be seen that when the interviewer indirectly said that this two faces matches, the responders recognize that and . But for the Figure 2 and 3 they disagreed with our mapping and responded that it only transmits a small similarity.

The more interesting part of the result can be seen if both results are combined. We can draw connections between table 1 and table 2 to see that the better the faces match each other the better can the emotion be matched in both photos presented separately. Figure 1 has the highest recognition rate as well as the highest rate of similarity between the two faces.

## Equipment restrictions

### Xbox 360 Kinect and Kinect for Windows

In this project we used an Xbox 360 Kinect to receive input from the Face Actors face. A Kinect for Windows would have been preferable against the Xbox 360 Kinect because it can register users closer to the Kinect. Accuracy from the depth sensor is better the closer the user is to the Kinect making closer range something to strive for. Another advantage the Kinect for Windows has over the Xbox 360 Kinect is that it allows skeleton tracking while the user is sitting.

The other advantages the Kinect for Windows has such as more RGB camera option, shorter and more reliable USB cable and faster and better translations of RGB coordinates and depth coordinates are not that relevant for this project.[16]

### Furhat

First of all the Furhat was made as a visual aid for speech synthesis, not for creating whole facial motions. Only two big regions can be change with the 16 parameters, the mouth and the eyes, greatly restricting the amount of expressions available. The only way to realistically animate a facial expression on a 3D model, you need to be able to change all points of that 3D models face.

## Alternative Solutions

### Calibrating Regions

Other face tracking programs calibrate each movable region of the face instead of calibrating an expression. There are several solutions doing this with Kinect as input but other output model[12]. Doing this should allow the Furhat to handle more expressions.

Calibration of each region of the face instead of whole expressions would allow regions to move instead of just whole expressions to move, but it takes more time to calibrate, implement and more hardware to run compared to the expression solution.

### Scientific Key Points

Choose key points in the mapping algorithm with scientific basis. Mapping method used in this project has key points defined by an unscientific discussion between the authors. With key points received on scientific basis the expressions could be better identified making clearer expressions on the Furhat.

## Sources of Error

### Mapping Process

The raw Kinect input is noisy and even with filtering the noise could have an effect on the result making the expressions unclear. Noise on the calibration data or runtime data could make that expression less accurate, the multiplication modifier for that expression would be lower and it is less likely for the Furhat to be able to express emotions.

Bad calibrations are another great source of error. Unrepresentative expressions for emotions from Face Actor or on Furhat or noisy Kinect data would result in a mapping that would be unrepresentative for given facial expression.

Equipment restrictions could have a negative effect on the result.

### Survey

For the survey there was only five paired facial expression whore used, five pairs is not the amount a scientific research would want to have. If more the five whore used that would have made the survey much more reliable, also this is a great source of error. Another source of error is the amount of persons and who did the survey. 31 students from KTH did the survey, half of those whores from the School of  Computer Science and Communication school. So this group of people has many things in common so the survey can represent the whole population. To only have 31 participating in the studies could not be enough so this could also be an error source.

## Conclusion

The Furhat did not replicate emotions that well with the mapping used in this project. When the difference between the expression of the Furhat face and the picture taken using the Kinects RGB camera was smaller, the better the emotion was translated from the Face Actor to the Furhat.

The essence of the four emotions selected can not be caught fully by the Furhat.

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# Appendix

## Appendix A -Processing Data

### Appendix A.1

**Table 5 (on next page) represents all data about the pair matching**

| | Survey number | | | | | |
|---|---|---|---|---|---|---|
| Pair | | 1 | 2 | 3 | 4 | 5 |
| | 1 | N | J | N | J | J |
| | 2 | N* | N | N | J | N |
| | 3 | J | J | N | J | J |
| | 4 | J | N | N | N | J |
| | 5 | N | N | N | N | J |
| | 6 | J | J | N | N | N*** |
| | 7 | J | N | N | N | N |
| | 8 | J | N | N | N | N |
| | 9 | J | N | N | N | J |
| | 10 | N | N | N | N | J |
| | 11 | J | N | N | J | J |
| | 12 | N | N* | N | J** | N |
| | 13 | N | N | N | N | N*** |
| | 14 | N* | N | J | N | J |
| | 15 | J | N | N | N | J |
| | 16 | N | N | N | N | J |
| | 17 | J | N | N | N | N |
| | 18 | J | N | N | N | N*** |
| | 19 | N* | N | N | N | N |
| | 20 | J | N | N | N | J |
| | 21 | J | N | N | N | N*** |
| | 22 | J | N | N | N | N*** |
| | 23 | J | N | N | N | N*** |
| | 24 | J | N | N | N | N*** |
| | 25 | J | N | N | N | N*** |
| | 26 | J | N | N | N | N |
| | 27 | J | N | N | N | J |
| | 28 | N | N | N | N | J |
| | 29 | J | N | N | N | J |
| | 30 | N | N | N | J | N |
| | 31 | N | N | N | N | N |
| | | *=Garderade sig fick rätt på ena alternativet | **=Mordisk och Elak samma sak | ***Nöjd != Glad | | |
| | | | | | | |
| | Total | 19/31 | 3/31 | 1/31 | 6/31 | 14/31 |
| | | | | | | ***8 /31 |

## Appendix A.2

**Table 6 Showing all input for the 3 part of the survey.**

| | Survey number | | | | | |
|---|---|---|---|---|---|---|
| Pair | | 1 | 2 | 3 | 4 | 5 |
| | 1 | 6 | 5 | 8 | 7 | 5 |
| | 2 | 8 | 4 | 2 | 4 | 7 |
| | 3 | 8 | 7 | 8 | 7 | 8 |
| | 4 | 8 | 6 | 6 | 6 | 7 |
| | 5 | 10 | 1 | 3 | 2 | 4 |
| | 6 | 5 | 2 | 3 | 7 | 10 |
| | 7 | 10 | 1 | 3 | 5 | 10 |
| | 8 | 8 | 3 | 5 | 5 | 6 |
| | 9 | 10 | 1 | 5 | 10 | 10 |
| | 10 | 8 | 4 | 5 | 6 | 5 |
| | 11 | 10 | 2 | 8 | 5 | 6 |
| | 12 | 8 | 3 | 6 | 8 | 9 |
| | 13 | 10 | 3 | 5 | 3 | 8 |
| | 14 | 8 | 5 | 1 | 4 | 8 |
| | 15 | 6 | 4 | 4 | 5 | 6 |
| | 16 | 9 | 3 | 4 | 5 | 7 |
| | 17 | 9 | 2 | 6 | 3 | 3 |
| | 18 | 7 | 1 | 2 | 8 | 8 |
| | 19 | 5 | 3 | 1 | 1 | 6 |
| | 20 | 10 | 6 | 1 | 5 | 7 |
| | 21 | 10 | 7 | 3 | 3 | 6 |
| | 22 | 8 | 6 | 7 | 7 | 8 |
| | 23 | 7 | 4 | 2 | 5 | 8 |
| | 24 | 9 | 2 | 3 | 6 | 8 |
| | 25 | 7 | 3 | 4 | 1 | 5 |
| | 26 | 7 | 4 | 2 | 4 | 3 |
| | 27 | 9 | 1 | 4 | 6 | 8 |
| | 28 | 10 | 6 | 5 | 6 | 5 |
| | 29 | 7 | 4 | 1 | 1 | 8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **30** | **5** | **3** | **5** | **9** | **4** |
| | **31** | **8** | **3** | **3** | **4** | **3** |
| | | **250** | **109** | **125** | **158** | **206** |
| | | | | | | |
| | | **Avg** | | | | |
| | | **8.06** | **3.51** | **4.03** | **5.09** | **6.64** |
| | **Precent** | **81%** | **35%** | **40%** | **51%** | **66%** |

# Appendix B – Answers from the survey

**In this appendix the free text answers from the survey is presented. From number 1 – 31.**

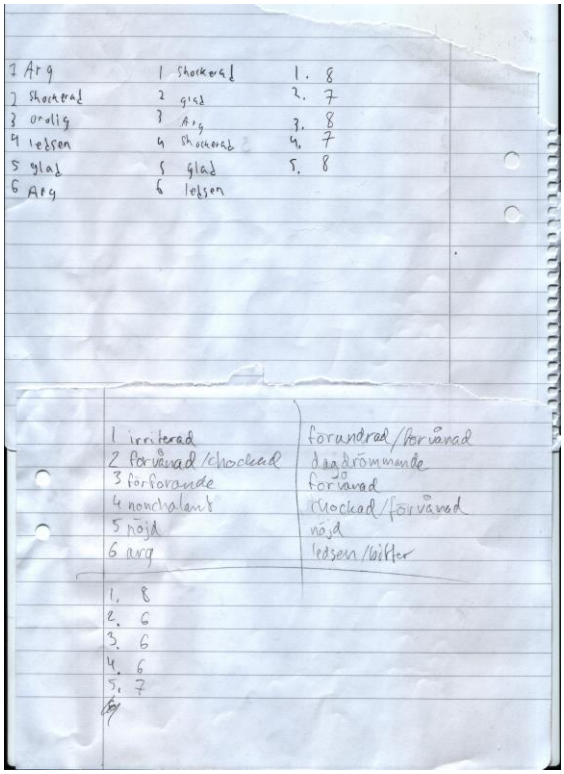


**Figure 1: Answers 1 and 2**

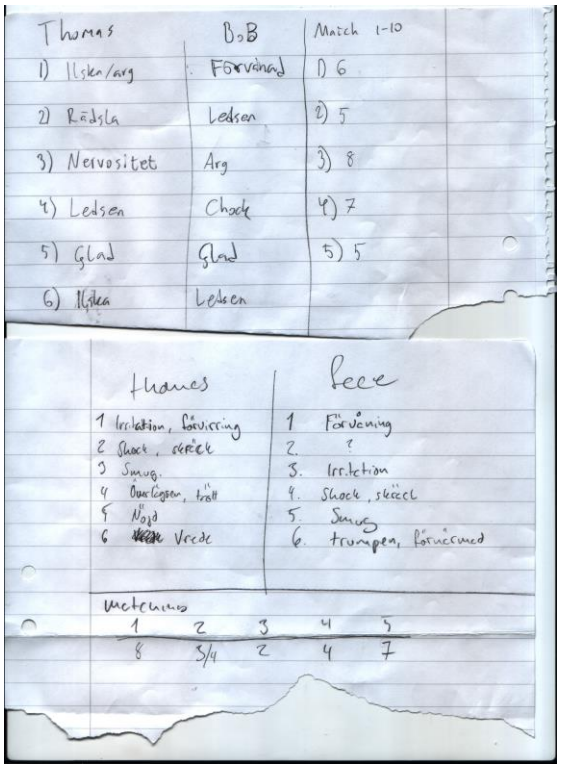


**Figure 2: Answers 3 and 4**

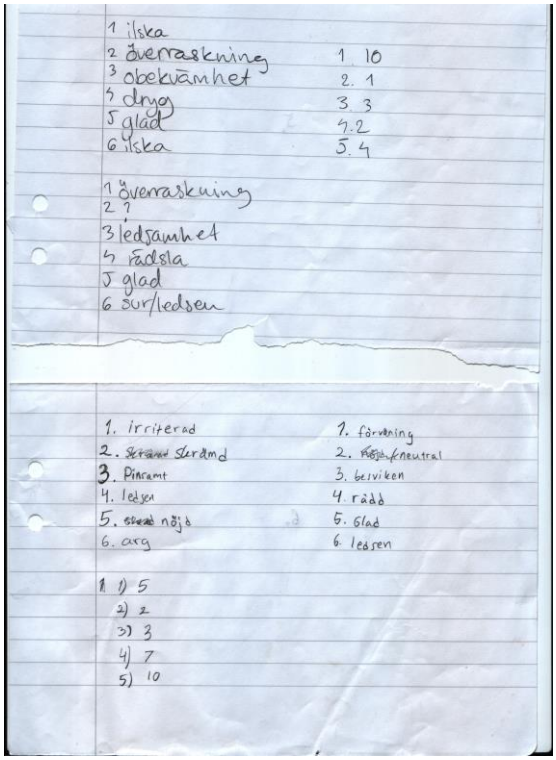


**Figure 3: Answers 5 and 6**

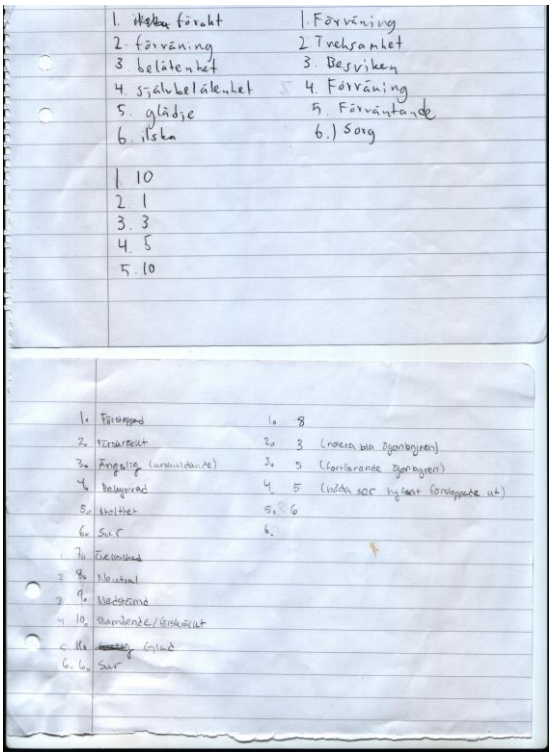


**Figure 4: Answers 7 and 8**

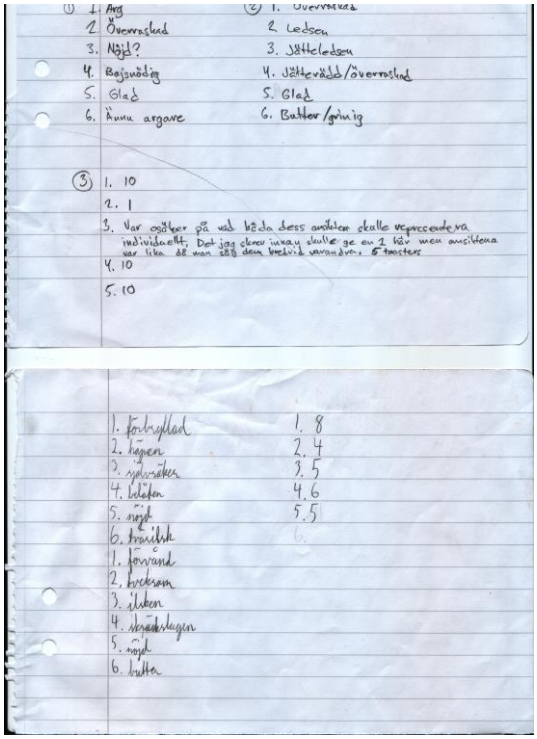

Figure 3: Answers 9 and 10

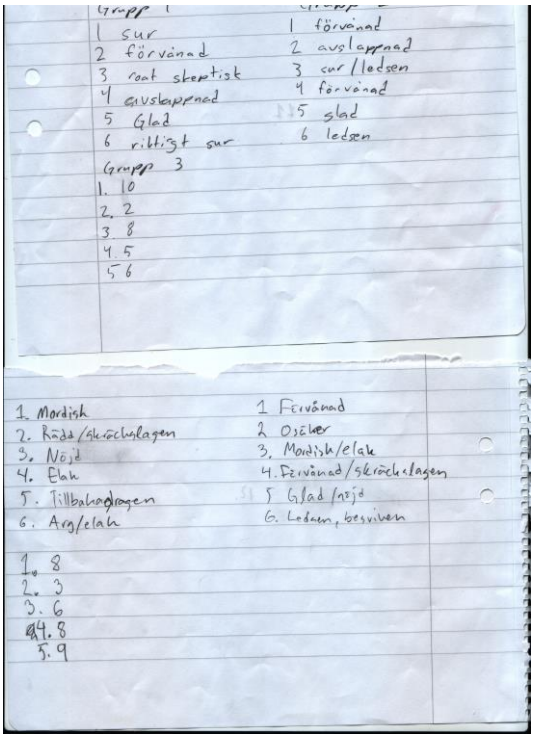

Figure 4: Answers 11 and 12

Figure 3: Answers 13 and 14

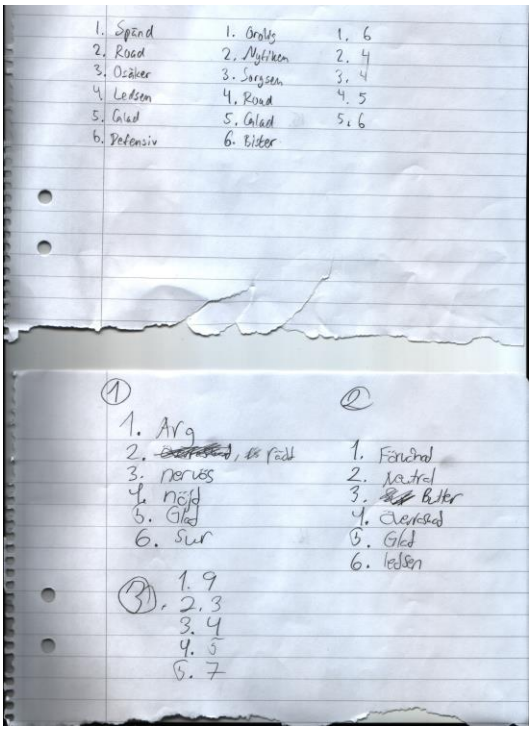

Figure 4: Answers 15 and 16

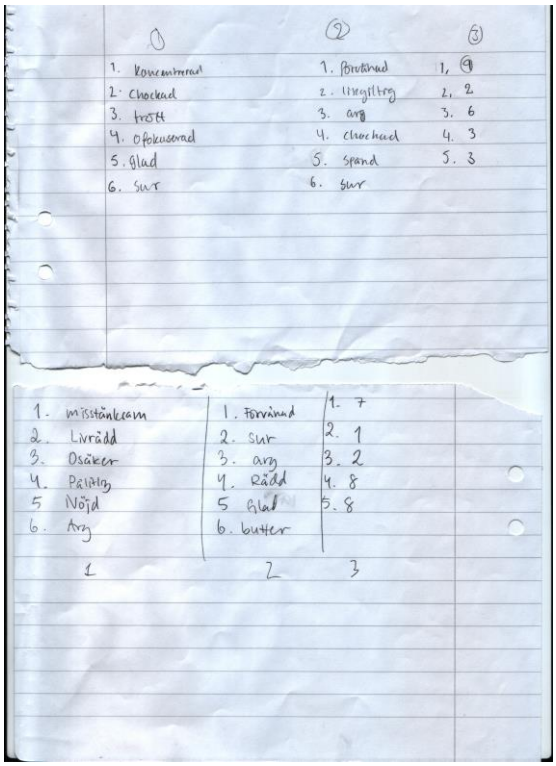

Figure 3: Answers 17 and 18

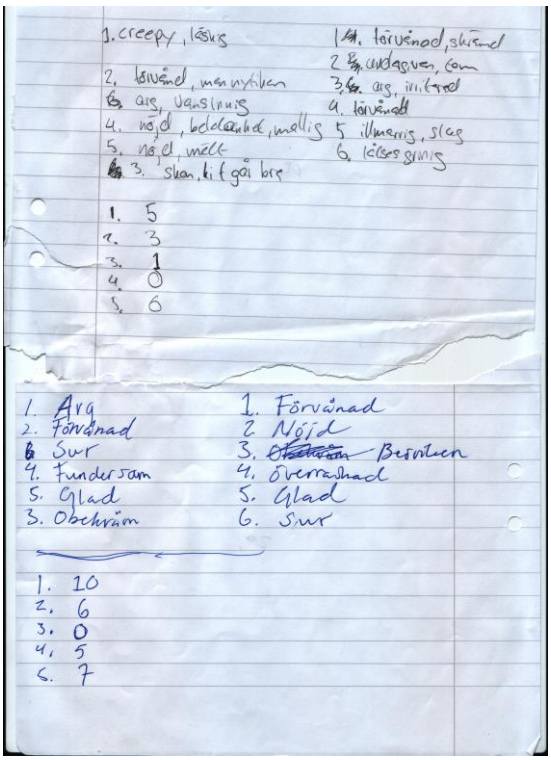

Figure 4: Answer 19 and 20

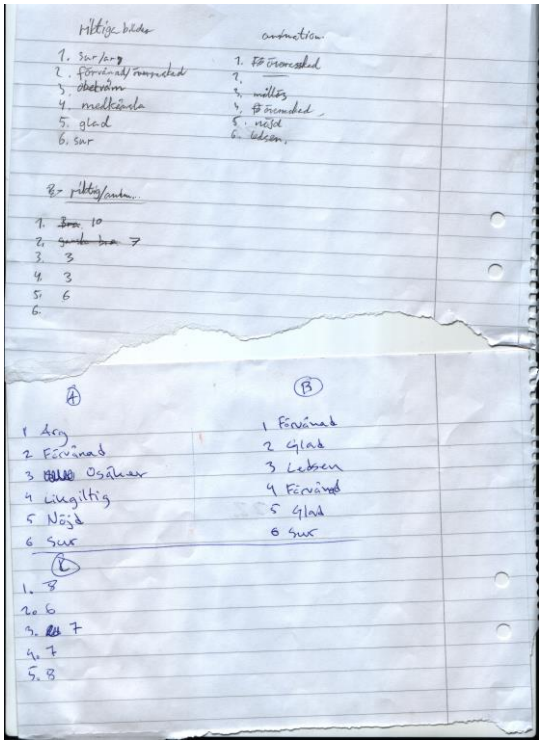

Figure 3: Answers 21 and 22

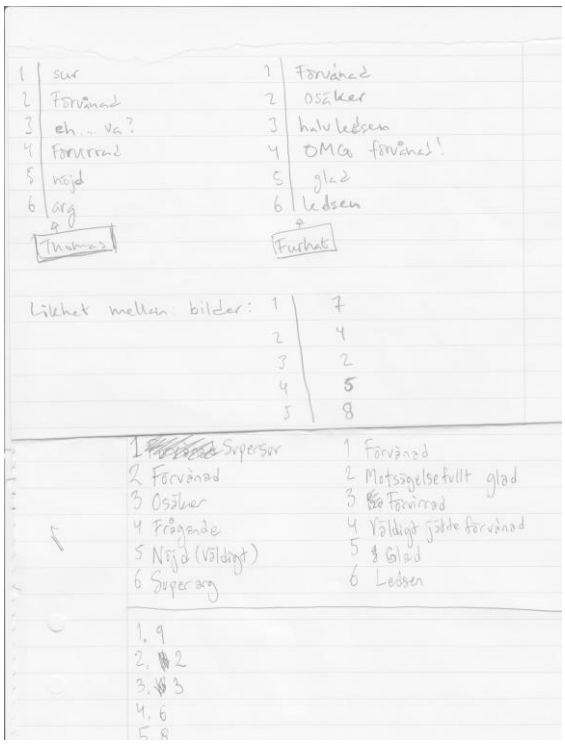

Figure 4: Answers 23 and 24

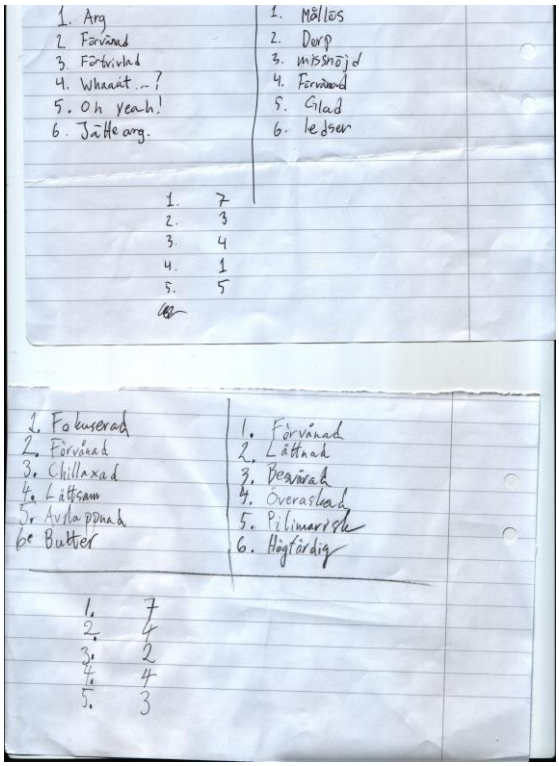


**Figure 3: Answers 25 and 26**

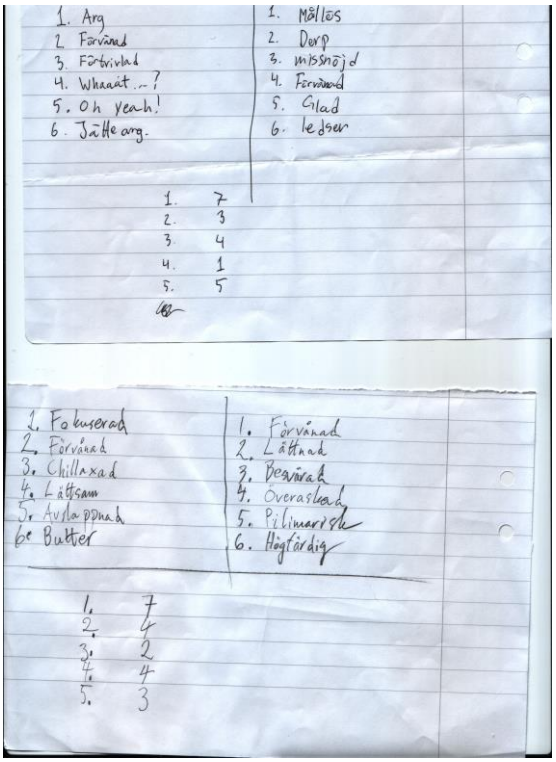


**Figure 4: Answers 27 and 28**

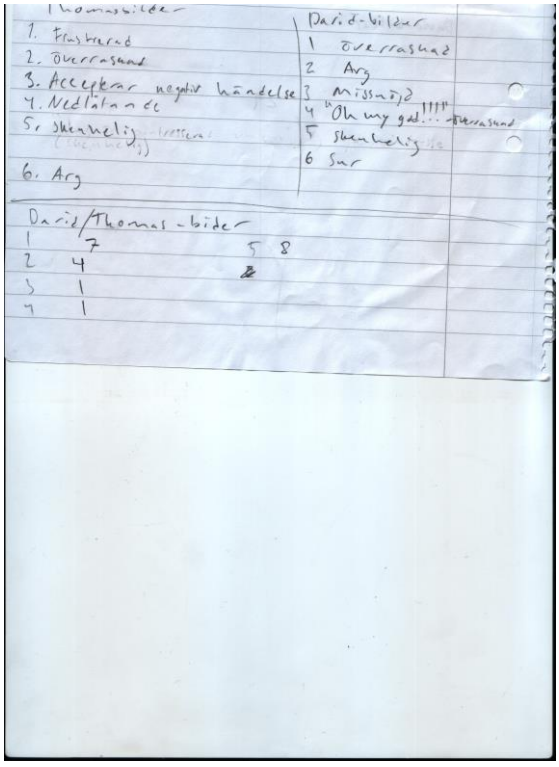


**Figure 3: Answer 29**

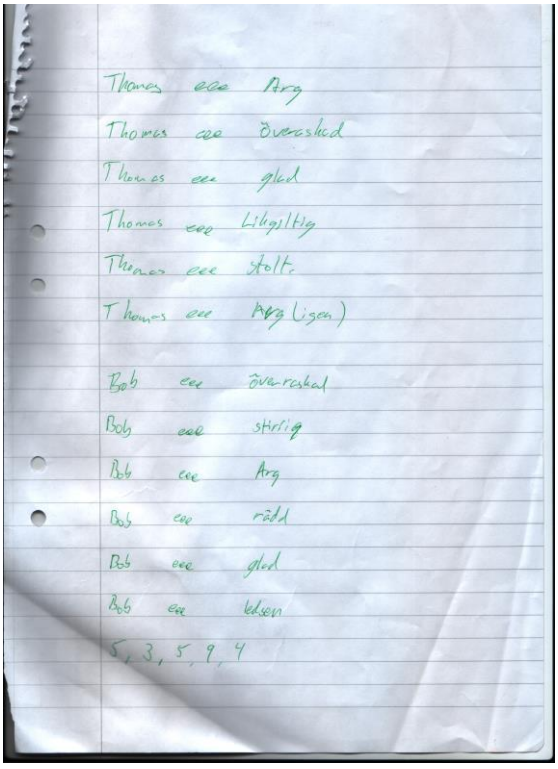


**Figure 4: Answer 30**

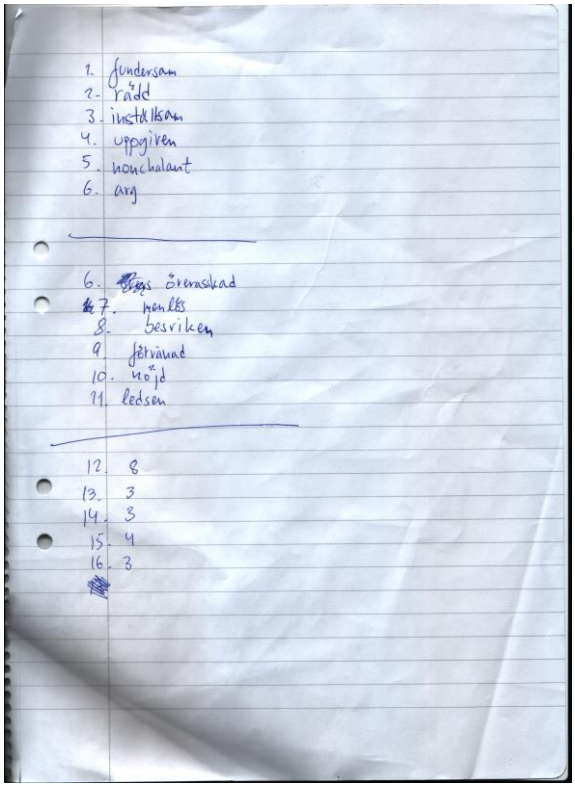


**Figure 3: Answer 31**

# Appendix C

## Appendix C.1

TopSkull = 0
TopRightForehead = 1
MiddleTopDipUpperLip = 7
AboveChin = 9
BottomOfChin = 10
RightOfRightEyebrow = 15
MiddleTopOfRightEyebrow = 16
LeftOfRightEyebrow = 17
MiddleBottomOfRightEyebrow = 18
AboveMidUpperRightEyelid = 19
OuterCornerOfRightEye = 20
MiddleTopRightEyelid = 21
MiddleBottomRightEyelid = 22
InnerCornerRightEye = 23
UnderMidBottomRightEyelid = 24
AboveRightNoseHole = 25 //Not Defined by Microsoft
UnderRightEar = 28 //Not Defined by Microsoft
RightSideOfChin = 30
OutsideRightCornerMouth = 31
RightOfChin = 32
RightTopDipUpperLip = 33
TopLeftForehead = 34
BetweenEyesAtNoseTop = 36 //Not Defined by Microsoft
UnderNoseWall = 39//Not Defined by Microsoft
MiddleTopLowerLip = 40
MiddleBottomLowerLip = 41
LeftOfLeftEyebrow = 48
MiddleTopOfLeftEyebrow = 49
RightOfLeftEyebrow = 50
MiddleBottomOfLeftEyebrow = 51
AboveMidUpperLeftEyelid = 52
OuterCornerOfLeftEye = 53
MiddleTopLeftEyelid = 54
MiddleBottomLeftEyelid = 55
InnerCornerLeftEye = 56
UnderMidBottomLeftEyelid = 57
AboveLeftNoseHole = 58//Not Defined by Microsoft
LeftSideOfCheek = 63
OutsideLeftCornerMouth = 64
LeftOfChin = 65
LeftTopDipUpperLip = 66
OuterTopRightPupil = 67
OuterBottomRightPupil = 68
OuterTopLeftPupil = 69
OuterBottomLeftPupil = 70
InnerTopRightPupil = 71
InnerBottomRightPupil = 72

InnerTopLeftPupil = 73
InnerBottomLeftPupil = 74
RightTopUpperLip = 79
LeftTopUpperLip = 80
RightBottomUpperLip = 81
LeftBottomUpperLip = 82
RightTopLowerLip = 83
LeftTopLowerLip = 84
RightBottomLowerLip = 85
LeftBottomLowerLip = 86
MiddleBottomUpperLip = 87
LeftCornerMouth = 88
RightCornerMouth = 89
BottomOfRightCheek = 90
BottomOfLeftCheek = 91
AboveThreeFourthRightEyelid = 95
AboveThreeFourthLeftEyelid = 96
ThreeFourthTopRightEyelid = 97
ThreeFourthTopLeftEyelid = 98
ThreeFourthBottomRightEyelid = 99
ThreeFourthBottomLeftEyelid = 100
BelowThreeFourthRightEyelid = 101
BelowThreeFourthLeftEyelid = 102
AboveOneFourthRightEyelid = 103
AboveOneFourthLeftEyelid = 104
OneFourthTopRightEyelid = 105
OneFourthTopLeftEyelid = 106
OneFourthBottomRightEyelid = 107
OneFourthBottomLeftEyelid = 108
UnderLeftEar = 113//Not Defined by Microsoft

## Appendix C.2

The Kinect points, called key points, used by the mapping algorithm are the following:

MiddleTopOfRightEyebrow = 16
LeftOfRightEyebrow = 17
MiddleBottomOfRightEyebrow = 18
MiddleTopOfLeftEyebrow = 49
RightOfLeftEyebrow = 50
MiddleBottomOfLeftEyebrow = 51
MiddleTopRightEyelid = 21
MiddleBottomRightEyelid = 22
MiddleTopLeftEyelid = 54
MiddleBottomLeftEyelid = 55
TopSkull = 0
UnderRightEar = 28//Not Defined by Microsoft
UnderLeftEar = 113//Not Defined by Microsoft
UnderNoseWall = 39//Not Defined by Microsoft
MiddleTopLowerLip = 40
MiddleBottomUpperLip = 87
LeftCornerMouth = 88
OutsideLeftCornerMouth = 64
RightCornerMouth = 89
OutsideRightCornerMouth = 31

## Appendix C.3

The following vectors are used by the mapping algorithm.

RIGHTEYELID = 0,
Is a vector between MiddleTopRightEyelid and MiddleBottomRightEyelid.

LEFTEYELID = 1,
Is a vector between MiddleTopLeftEyelid and MiddleBottomLeftEyelid.

RIGHTEYEBROW_TO_TOP = 2,
Is a vector between MiddleTopOfRightEyebrow and TopSkull.

LEFTEYEBROW_TO_TOP = 3,
Is a vector between MiddleTopOfLeftEyebrow and TopSkull.

RIGHTEYEBROWCENTER_TO_CHEEK = 4,
Is a vector between MiddleBottomOfRightEyebrow and UnderRightEar.

RIGHTEYEBROWEDGE_TO_CHEEK = 5,
Is a vector between LeftOfRightEyebrow and UnderRightEar.

LEFTEYEBROWCENTER_TO_CHEEK = 6,
Is a vector between MiddleBottomOfLeftEyebrow and UnderLeftEar.

LEFTEYEBROWEDGE_TO_CHEEK = 7,
Is a vector between RightOfLeftEyebrow and UnderLeftEar.

RIGHTCHEEK_TO_MOUTH = 8,
Is a vector between OutsideRightCornerMouth and UnderRightEar.

LEFTCHEEK_TO_MOUTH = 9,
Is a vector between OutsideLeftCornerMouth and UnderLeftEar.

RIGHTOFMOUTH_TO_NOSE = 10,
Is a vector between OutsideRightCornerMouth and UnderNoseWall.

LEFTOFMOUTH_TO_NOSE = 11,
Is a vector between OutsideLeftCornerMouth and UnderNoseWall.

MOUTH_EDGES_LEFT_RIGHT = 12,
Is a vector between LeftCornerMouth and RightCornerMouth.

MOUTH_EDGES_TOP_BOT = 13,
Is a vector between MiddleBottomUpperLip and MiddleTopLowerLip.

RIGHTMOUTHEDGE_TO_BOT_CENTER = 14,
Is a vector between RightCornerMouth and MiddleTopLowerLip.

LEFT_MOUTH_EDGE_TO_BOT_ECNTER = 15;
Is a vector between LeftCornerMouth and MiddleTopLowerLip.

# Appendix D

The Kinect data of the five predefined expressions. This data is the sum of eight successfully captured frames and should be divided by eight to use it as an average single frame.

Neutral Face

| Point Index | X | Y | Z |
|---|---|---|---|
| 0 | 0,02535704 | 2,76567262 | 12,21789765 |
| 1 | -0,14541096 | 2,59192005 | 11,85693872 |
| 2 | -0,01465588 | 2,28157735 | 11,71740186 |
| 3 | -0,04039809 | 2,05356026 | 11,66283226 |
| 4 | -0,04843830 | 1,99121815 | 11,67423987 |
| 5 | -0,08836379 | 1,60963154 | 11,50004673 |
| 6 | -0,09732600 | 1,55903974 | 11,57334614 |
| 7 | -0,11197154 | 1,42746387 | 11,53639805 |
| 8 | -0,13046228 | 1,27062938 | 11,51950419 |
| 9 | -0,14054519 | 1,20004955 | 11,55819488 |
| 10 | -0,17661967 | 0,90715878 | 11,56712902 |
| 11 | -0,17737664 | 2,76999408 | 12,20727730 |
| 12 | -0,41065240 | 2,68373400 | 12,14158928 |
| 13 | -0,40939194 | 2,45076096 | 11,90416968 |
| 14 | -0,59132409 | 2,36248907 | 12,08589542 |
| 15 | -0,53495185 | 2,09171775 | 11,84838891 |
| 16 | -0,38950902 | 2,17616159 | 11,73453951 |
| 17 | -0,15345644 | 2,05582535 | 11,65689242 |
| 18 | -0,39504371 | 2,12859109 | 11,72746897 |
| 19 | -0,31981685 | 2,01566693 | 11,74461067 |
| 20 | -0,46323281 | 1,94666731 | 11,82950222 |
| 21 | -0,32221230 | 1,99446523 | 11,73958063 |
| 22 | -0,33069719 | 1,92153598 | 11,72873855 |
| 23 | - | 1,92865853 | 11,73749959 |

| | | | |
|---|---|---|---|
| | 0,19088653 | | |
| 24 | -0,33261948 | 1,90501375 | 11,72628248 |
| 25 | -0,19092515 | 1,65873437 | 11,66426849 |
| 26 | -0,26021039 | 1,58646834 | 11,65015304 |
| 27 | -0,44667906 | 1,72359663 | 11,73654342 |
| 28 | -0,62760068 | 1,56770200 | 11,97086430 |
| 29 | -0,63972366 | 1,93844604 | 12,02291358 |
| 30 | -0,60181131 | 1,20623656 | 11,92089224 |
| 31 | -0,36204270 | 1,38698727 | 11,66348720 |
| 32 | -0,33620100 | 0,95414409 | 11,61983979 |
| 33 | -0,14935680 | 1,45050117 | 11,53216326 |
| 34 | 0,17595517 | 2,55271396 | 11,86917210 |
| 35 | -0,01465588 | 2,28157735 | 11,71740186 |
| 36 | -0,04131384 | 2,04568940 | 11,66166270 |
| 37 | -0,04935405 | 1,98334730 | 11,67307043 |
| 38 | -0,08927954 | 1,60176060 | 11,49887645 |
| 39 | -0,09824176 | 1,55116889 | 11,57217586 |
| 40 | -0,12523854 | 1,32274987 | 11,54933834 |
| 41 | -0,12469576 | 1,31580432 | 11,51275504 |
| 42 | -0,13380685 | 1,25071381 | 11,54348993 |
| 43 | -0,16383041 | 1,00618848 | 11,54849064 |
| 44 | 0,22340753 | 2,72109926 | 12,22253382 |
| 45 | 0,43339537 | 2,58076176 | 12,17371905 |
| 46 | 0,39402340 | 2,35274553 | 11,93475258 |
| 47 | 0,53530430 | 2,22504225 | 12,12878239 |
| 48 | 0,43352129 | 1,97356613 | 11,88525522 |
| 49 | 0,32155386 | 2,08941430 | 11,76160657 |
| 50 | 0,07001359 | 2,02856424 | 11,66539764 |
| 51 | 0,31601920 | 2,04184380 | 11,75453520 |
| 52 | 0,21393253 | 1,94283982 | 11,76383281 |
| 53 | 0,32981479 | 1,84220621 | 11,85859489 |
| 54 | 0,21153708 | 1,92163810 | 11,75880194 |
| 55 | 0,20305221 | 1,84870885 | 11,74796069 |
| 56 | 0,06878919 | 1,88926792 | 11,74628806 |

| | | | |
|---|---|---|---|
| 57 | 0,20112990 | 1,83218654 | 11,74550462 |
| 58 | 0,01039039 | 1,63417427 | 11,67193174 |
| 59 | 0,06115574 | 1,54726227 | 11,66238630 |
| 60 | 0,26808349 | 1,63639686 | 11,76375163 |
| 61 | 0,38821175 | 1,44377467 | 12,00953281 |
| 62 | 0,48505785 | 1,80122466 | 12,06572974 |
| 63 | 0,28021060 | 1,09863143 | 11,95446801 |
| 64 | 0,11083024 | 1,32930335 | 11,68148243 |
| 65 | -0,01483487 | 0,91493801 | 11,63207316 |
| 66 | -0,06993873 | 1,44081232 | 11,53518629 |
| 67 | -0,36474285 | 1,99233067 | 11,76517212 |
| 68 | -0,37359805 | 1,91621888 | 11,75385833 |
| 69 | 0,25027151 | 1,90958935 | 11,78748739 |
| 70 | 0,24141631 | 1,83347754 | 11,77617276 |
| 71 | -0,28809519 | 1,98297977 | 11,76809037 |
| 72 | -0,29695040 | 1,90686797 | 11,75677574 |
| 73 | 0,17362384 | 1,91894026 | 11,78456926 |
| 74 | 0,16476864 | 1,84282835 | 11,77325547 |
| 75 | -0,16508781 | 1,61262195 | 11,55272460 |
| 76 | -0,01733327 | 1,59459619 | 11,55834937 |
| 77 | -0,06987642 | 1,99081755 | 11,69371367 |
| 78 | -0,02924392 | 1,98586050 | 11,69526064 |
| 79 | -0,23401358 | 1,43396005 | 11,60696864 |
| 80 | 0,00242288 | 1,40511818 | 11,61596572 |
| 81 | -0,21789720 | 1,38555761 | 11,61322284 |
| 82 | -0,02526588 | 1,36205949 | 11,62055254 |
| 83 | -0,22410990 | 1,33637758 | 11,61885071 |
| 84 | -0,03147858 | 1,31287946 | 11,62618124 |
| 85 | -0,25003850 | 1,30045520 | 11,60006440 |
| 86 | -0,01360205 | 1,27161324 | 11,60906160 |
| 87 | -0,11737054 | 1,38616078 | 11,54582655 |
| 88 | -0,31955000 | 1,37727942 | 11,68564570 |
| 89 | 0,06571264 | 1,33028318 | 11,70030594 |
| 90 | - | 1,39648809 | 11,69934952 |

| | | | |
|---|---|---|---|
| | 0,46104805 | | |
| 91 | 0,20624474 | 1,31508207 | 11,72474802 |
| 92 | -0,12993906 | 1,82471968 | 11,67900896 |
| 93 | -0,00988850 | 1,81007369 | 11,68357825 |
| 94 | -0,06310664 | 1,86053275 | 11,64071739 |
| 95 | -0,38995339 | 1,99451964 | 11,78857195 |
| 96 | 0,27344505 | 1,90587558 | 11,81272852 |
| 97 | -0,39155447 | 1,98075849 | 11,78652620 |
| 98 | 0,27184399 | 1,89211443 | 11,81068277 |
| 99 | -0,39794968 | 1,92579176 | 11,77835536 |
| 100 | 0,26544878 | 1,83714761 | 11,80251193 |
| 101 | -0,39947305 | 1,91607991 | 11,78724933 |
| 102 | 0,26392541 | 1,82743585 | 11,81140590 |
| 103 | -0,25441773 | 1,98387933 | 11,75407386 |
| 104 | 0,14229486 | 1,92777047 | 11,76807916 |
| 105 | -0,25601879 | 1,97011830 | 11,75202811 |
| 106 | 0,14069380 | 1,91400941 | 11,76603341 |
| 107 | -0,26241400 | 1,91515146 | 11,74385726 |
| 108 | 0,13429857 | 1,85904260 | 11,75786257 |
| 109 | -0,26393737 | 1,90543970 | 11,75275123 |
| 110 | 0,13277520 | 1,84933084 | 11,76675653 |
| 111 | -0,20936576 | 1,56941822 | 11,59121537 |
| 112 | 0,01226603 | 1,54237950 | 11,59965169 |
| 113 | 0,39694595 | 1,39171173 | 12,35294509 |
| 114 | 0,49471549 | 1,74904904 | 12,40917706 |
| 115 | 0,52613939 | 2,09963545 | 12,46077287 |
| 116 | 0,46763296 | 1,70437156 | 12,73093629 |
| 117 | -0,67427444 | 1,52239867 | 12,31216741 |
| 118 | -0,68732083 | 1,89325538 | 12,36418164 |
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