BACHELOR THESIS

Animation of robot for Emotion Expression: Ocular Expression and Animation of TUK

(Technische Universität Kiwi)

Submitted to the Institute for Computer Technology
Faculty of Electrical Engineering and Information
TU Wien
in partial fulfilment of the requirements for the degree of
Bachelor of Sciences

under supervision of

Dr. Nima Taherinejad, Technische Universität Wien
Dra. Sandra Baldassarri, University of Zaragoza

by

Pinilla Sediles, Elena
Matr.Nr. 1528277

9th August, 2016

Abstract

This project deals with the design of the ocular expression and animation of TUK, an animal-like robot developed in order to help autistic children.

The target of this thesis is to design and build a structure for the required actuators, as well as covering their implementation and control. Eyes, eyelids and the pieces which are part of the different mechanisms will be manufactured. Finally, a set of expressions for the robot will arise as a result of the developed movements.

Apart from these technical aspects, the fact that this project has a therapeutic aim concerning children with autism cannot be forgotten. As a result, during the design, factors such as a friendliness, robustness, safety, cleanliness, and appeal have been kept in mind.

Kurzfassung

Dieses Projekt befasst sich mit dem Design des Augenausdrucks und Zeichentrickfilm von TUK, ein tierähnlicher entwickelter Roboter, um autistischen Kindern zu helfen.

Das Ziel dieser These soll entwerfen und eine Struktur für die erforderlichen Auslöser, sowie Bedeckung ihrer Durchführung und Kontrolle bauen. Außerdem werden Augen, Augenlider und die Stücke, die ein Teil der verschiedenen Mechanismen sind, verfertigt. Schließlich wird eine Reihe von Ausdrücken für den Roboter infolge der entwickelten Bewegungen entstehen.

Abgesondert vom technischen Punkt kann die Tatsache, dass dieses Projekt ein therapeutisches Ziel bezüglich Kinder mit Autismus hat, nicht vergessen werden. Infolgedessen, während der Designthemen wie eine Freundlichkeit, sind Robustheit, Sicherheit, Reinheit und Charme beachtet worden.

Acknowledgements

First of all, I wish to express my sincere thanks to Nima Taherinejad from the Technische Universität Wien and Sandra Baldassarri from the University of Zaragoza for their valuable contributions as Bachelor Thesis Supervisors.

I am grateful to the Technische Universität Wien, for providing me with all facilities necessary for my research, especially to Friedrich Bauer.

Furthermore, I am thankful to all the lecturers I had the priviledge of learning from during my degree. I am extremely grateful and indebted to them for sharing their expertise and providing sincere and valuable guidance and encouragement to me during the last four years.

I would also like to take this opportunity to express gratitude to my entire family, classmates and colleagues for their help, unceasing encouragement and attention throughout this venture.

Last but not least, a very special mention to Mike Lake, father of Jaden, for his knowledge and endless generosity towards the cause.

–Thank you, everyone!–

"I haven't failed. I have just found 10,000 ways that won't work."
- Thomas Alva Edison

It is not related in this report (neither is it its aim) the innumerable times that, symbolically, the devised possibilities have been crumpled, thrown into the bin and discarded whilst searching for the suitable solution. This quotation encourages us all to keep going instead of giving up.

Table of Contents

Abbreviations

ASD Autism Spectrum Disorder

CAD Computer-aided Design

DOF Degree of Freedom

EPS Expanded Polystyrene

EVA Ethylene-vinyl acetate

FFC Flex Flat Cable

HD High Definition

IDE Integrated Development Environment

I/O Inputs/Outputs

ISR Interruption Service Routine

LED Light-emitting diode

PCB Printed Circuit Board

PDD-NOS Pervasive Developmental Disorder-Not Otherwise Specified

PLA Polylactic acid

PWM Pulse Width Modulation

SMD Surface-Mounted Device

TUK Technische Universität Kiwi

1 Introduction

This report follows a structure which tries to set forth the steps taken throughout the progression of this thesis. This first chapter explains the motivation that stimulates the whole project which expands beyond this thesis. Then, the objectives pursued are explained alongside the problems that are to be solved. Later, the methods devised to solve these problems are related achieving the stated goals, as well as the project highlights. In the second chapter, the state of the art technology is presented, analysed and compared. The third chapter continues detailing the methodology and the used concepts. After that, in the fourth chapter the design process is described and in the fifth chapter the manufacturing and implementation procedures are outlined. Two final sections conclude this report with a critical reflection, a summary and the future work.

1.1 Motivation

Autism is a neurodevelopmental disorder characterised by impaired social interaction, verbal and non-verbal communication, and restricted and repetitive behaviour [1]. Autism affects information processing in the brain by altering how ribs cells and their synapses connect and organise themselves [2]. It is one of the three disorders recognised in the autism spectrum (ASDs), the other two being Asperger's Syndrome, characterised by delays in cognitive development and language, and Pervasive Developmental Disorder (PDD-NOS) [3].

Every 11 minutes a child with Autism is born [4]. And alongside those with Asperger's Syndrome, children with autism are unlikely to exhibit social understanding, approach others spontaneously, express and respond to emotions and communicate non-verbally. They experience difficulties in basic social interaction, which may lead to difficulties developing friendships, seeking similarities and/or shared accomplishments. This is the result of the lack of the cognitive component of empathy, also called "theory of mind", which enables the person to understand other people's emotions [5].

Traditional treatments attempt to maximise the child's functional independence and quality of life and teach age-appropriate social, communication and vocational skills by minimising the autism spectrum features. All this is trying to be achieved by facilitating development and learning, promoting socialisation, reducing maladaptive behaviours, and educating and supporting families. Behavioural interventions help children with autism gain self-care, social and communication skills [1][6]. Thus, TUK aims to be a tool which can help to develop these ideas and therapies, whose efficacy is demonstrated.

TUK, as can be seen in Figure 1, it is just a stuffed animal. However, it aspires to be much more than that; it is planned to add to be a companion, a therapeutic learning tool. Moreover, if TUK's future abilities are to be taken into account, it could be considered as a medical or rehabilitative robot.

The Encyclopaedia Britannica defines empathy as "the ability to imagine oneself in another's place and understand the other's feelings, desires, ideas, and actions"[7]. It is asserted that empathy is composed of a "cognitive"component, which refers to the capacity to understand another's perspective or mental state; and the "affective"component, which is, by contrast, the ability to respond with an appropriate emotion to another's mental state. The theory of mind alludes to the cognitive empathy, as previously mentioned [8].

Figure 1: TUK

Some individuals, which include people with ASD, may develop empathy belatedly. As this impacts their social interaction, a challenge around whether aspects of empathy can be taught is raised. After numerous studies with satisfactory results, it has been demonstrated that cognitive empathy can indeed be taught [8][9].

As far as the teaching of empathy is concerned, the different therapies working to achieve this are based on another trait of people suffering from ASD - their propensity to systematise. By systematising, the rules that govern a system are identified to predict how a system behaves.

In order to make TUK efficient and compelling, heed must be paid to the theories and studies mentioned above. Learning to express emotions by way of TUK reduces the difficulties these children have when dealing with the social world - as it is always changing and the outcome is different every time [8][9].

1.2 Objectives

This work deals with the automation of TUK through suitable electromechanical actuators, sensors and structures. The purpose is to make it into a therapeutic tool to help children understand the emotions of others and express themselves (empathy). As it is directed to a young public, reinforcement, resistance, and cleanliness are principal issues in the design of the model. This fact will limit the movements, covers, and rigid structures that form part of the prototype.

The three primary objectives of this thesis are to catch children's attention and make TUK expressive and useful for therapy.

Firstly, a stuffed animal such as TUK should be friendly. With its simplicity and roundness, it has the potential to become a child's favourite soft toy.

Secondly, to work on expressiveness, TUK will be equipped with different elements analogous to those which humans use to communicate feelings and emotions:

- Artificial vision through two cameras as eyes, whose images will be processed by an algorithm to recognise the feelings of the child;
- Ability to make movements through eyes and eyelids.

The six emotions defined as "basic" emotions by the expert in facial expression, Paul Ekman [10], are portrayed: happiness, sadness, anger, fear, disgust and surprise.

As far as the third matter is concerned, there are four areas of development to be dealt with in a child:

- Cognitive Area: refers to mental processes such as imagination or the executive function;
- Social Area: abilities to socialise, social recognition, character, autonomy, etc.;
- Communication: expression and perception;
- Motor-sensory area.

Consequently, the robot will be seen as a tool of positive encouragement. It will always act in the same way, which will create a sense of control. The child will feel safe and be guided towards the acquisition of new social abilities [11].

1.3 Methodological approach

To accomplish this project, knowledge of electronic and electrical engineering acquired during the bachelor degree has been utilised. From this perspective, a knowledge of mechanical engineering and techniques of product design has been applied.

Firstly, when it comes to electronic and electrical matters:

- Micro-controller acquisition: the number and type of I/O essential to connect every component, the power supply and programming requirements are factors to have in mind;
- Connections: an electronic connection among the elements is a dominant regard;
- Software programming: know-how about programming and its possibilities are requisites to create the software which controls and commands the performance of the actuators.

Secondly, as far as applied mechanics are concerned:

- Motors selection: carrying out an analysis of each motor necessary features. For instance, the torque they offer to cover the weight requirements and movement length (lever arm) in the worst-case scenario for each mechanism;
- Motor placement: as rotational motions are handled, the axis of the motor has to match with the one desired as a motion centre, also searching for a null lever arm;
- Pieces design: the tension distribution along elements has to be taken into account. Every part is adapted by sizing or shaping paying attention to where the risk of breakage is;
- Movements establishment: according to the movements which are to be endowed, the necessary degrees of freedom (DOF) are set. For each eye and eyelid, movement along two perpendicular rotational axes (two DOF) is required;
- Joints design: evaluation of the fastenings, the motion to be impelled and the force which should be imposed.

Finally, regarding the product design:

- Layer printing conception: keeping in mind that the 3D printer prints by layer, some details or requirements are not feasible, forcing a change in plans;

- Materials choice: The suitable material is defined by design, size, weight, strength conditions and different stresses to which the elements react;
- Components positioning: a robust and steady structure which may be placed inside TUK also defines the design and fastenings among the parts.

1.4 Project Highlights

As far as the highlights of this work are concerned, the elements of the animation are developed, as well as the software which manages them. These items are:

- The supporting structure, which provides stability, support and assembly of the components;
- Cameras: TUK's vision has been set up through the eyes;
- Designs for the eyes case have been created, providing a human appearance;
- Designs for the eyelids, to characterise natural emotions expressed by eyebrows and eyelids;
- Mechanisms to move the eyelids with the purpose of showing TUK's feelings;
- Programmed software implemented in a microcontroller to guide and control the motions;
- Analysis of problems and the corresponding search for solutions; plans for future work.

2 State of the art

2.1 Literature studies

The research on socially assistive robots for children with autism is still at an early stage, and many devices have not yet been applied therapeutically. Nevertheless, they are being used to assist elderly people and recovering stroke victims during physical therapy [12]. The most refined designs applied in treatments related to social behaviour are described below.

One of the most widespread robotic tools is PARO, a furry robot that looks like a baby harp seal. PARO, seen in Figure 2, has been developed by a Japanese industrial automation pioneer, AIST [13]. It has five kinds of sensors: tactile, light, audition, temperature, and posture. As a result, PARO acts as if it were alive, moving head and legs, making sounds, and behaving in a way preferred by the user. It also reacts to petting, heat, and sounds. It learns to repeat or avoid actions by analysing the operator's response to them. Moreover, it can be named and reacts when called.

Figure 2: PARO Therapeutic Robot

It has been stated that the robot stimulates social interactions. However, it costs more than €6000. This is a common problem in robotics research; it is expensive, and funding is hard to come by [12][13].

A second example of a robot for autistic kids is Popchilla, which can be found in Figure 3. It has been developed by an American start-up, Interbots [14]. Equipped with mobile paws, eyelids, mouth and ears and colour LEDs in its eyes and sound system, Popchilla is capable of expressing anger, happiness, surprise, confusion and sadness. Its expressive face teaches autistic children to pick up on social cues. Children have reacted very well to the robot and are interested by it [15].

Figure 3: Popchilla Robot

Popchilla is wirelessly controlled via laptop or iPad. As a result, it is possible for a therapist to control Popchilla's emotions through his ears position, eyes colour, eyelids and head movements.

Although Popchilla is not the only robot designed for autistic children, it is likely the most affordable option. At €300, its price is relatively low [14][16].

A third representative sample of these therapeutic robots is Keepon Pro, shown in Figure 4. It has two cameras in each eye, a built-in microphone in its nose and four motors at the base. It has two modes: touch and dance [12].

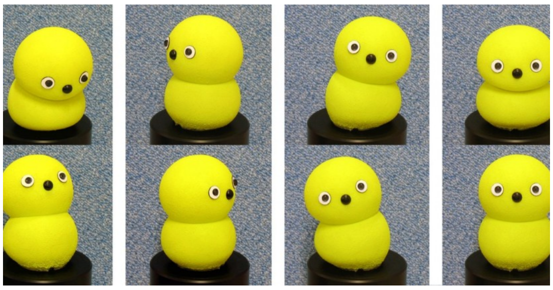


Figure 4: Keepon Pro Robot

On the one hand, in touch mode, it responds to pokes, taps, squeezes, pats, and tickles with sounds and movements to express emotions such as excitement, curiosity or sleep.

On the other hand, in dance mode, Keepon Pro dances in time to the rhythm of clapping, patting or music. Such a performance is made possible due to its microphone and beat detector.

According to researchers, children who are overwhelmed with the complexity of human behaviour (such as autistic children), find it a successful tool for social interaction[17].

Finally, the last example of inspiring robots for children with autism is NAO, from Aldebaran Robotics [18]. It is an autonomous and interactive humanoid robot that can be programmable. It has been used to develop social skills in children with Asperger's Syndrome or autism. The various versions of NAO feature either 14, 21 or 25 DOF. In addition to this, its inertial measurement unit provides it with stability and positioning in a certain space. It is also endowed with multiple sensors and sonars. NAO can be seen in Figure 5.

Figure 5: NAO Humanoid Robot

NAO has four directional microphones and two loudspeakers, for multilingual text-to-speech synthesis, voice recognition and sound localisation. These features allow NAO to interact with humans in a natural manner. NAO is also equipped with two HD cameras for facial and shape recognition and an Internet connection. On account of these facts, it is not surprising that the robot costs €7000.

ASK NAO (Autism Solution for Kids) is a tool developed by Aldebaran Robotics for NAO, to support teachers from schools or health care institutions who work with autistic children. It entails several applications for Special Education. As a result, teachers can now focus on guiding children rather than on prompting and systematic instructions [18][19].

All these therapeutic robots have shown that children need no persuasion or external reinforcement to interact. The robots also exhibit that, rather than expecting children with ASD to join the world, the environment should be adapted to meet them halfway [9].

2.2 Comparison and analysis of existing approaches

In Table 1, the most appealing and relevant features of the previous examples of interactive robots - in comparison with those TUK offers or plans to offer - are gathered. The adjectives attributed are qualitative and relative to the overall.

Features	**Paro**	**Popchilla**	**Keepon Pro**	**NAO**	**TUK**
Therapy	Disabled	Autism	Autism	Education	Autism
Size	Big >55cm	Small <30cm	Small <30cm	Big >55cm	Medium >30cm
Weight	2.7kg		0.9kg	4.3kg	
Customizable	Simple	Programmable /Ipad	Controlled by PC	Yes	Yes
Price	€6000	<€300		€7000	<€300
Softness	High	High	Low	Low	High
Washable	No	No	No	No	Yes
Facial Expression	No	Low	No	No	High
Cameras	No	No	Yes	No	Yes
Answer to visual stimuli	No	No	Yes	No	Yes
Sensors	Touch	No	Beating	Voice	Touch + Voice

Table 1: Comparative chart between TUK and therapeutic robots already in the market

This table will be completed and improved as the project evolves. As a conclusion, it may be noted that the strengths of TUK are its price, its washable and customisable design, its expressiveness and its high capability to interact.

Price has been a critical factor throughout the planning and construction of TUK. Cheap materials such as wood and PLA have been used, as well as an inexpensive Arduino board for the control.

To make TUK washable, an "egg" shape case has been devised which hosts all components. The fur cover will be tailored with a zip which allows this egg to be taken out and TUK to be washed.

TUK also makes a difference through its versatility. This project has been conceived to be able to bring these innovative techniques available to whoever needs them. The pieces are manufactured by a 3D printer, an increasingly widespread form of technology which is easily accessible. As well as this, the control is performed by the open-source Arduino Software (IDE), which makes TUK a viable and competitive proposal.

In addition to this, the expressiveness is provided through as many DOF as are needed to make TUK as human as possible. Several motors (one per DOF) have been constructed.

In a nutshell, the intention of TUK and its manufacturers is to design useful robot for autistic kids, which is accessible to everyone.

2.3 Conclusions from the comparison

These four examples show that the biggest barrier to be overcome is the affordability of the robots. Although there is still a lack of gestural expressiveness in these robots, their potential and effectiveness cannot be denied. Hence, cheaper alternatives should be pursued and promoted for such a beneficial tool. The aim here is to develop a more expressive and emphatic robot - a robot which is also friendly and appealing, as part of an attempt to get more favourable results.

Once the state of the art technology has been analysed, the goals for the project are set. The goals that will guide the whole process and define the decisions are:

- Expressiveness: to make TUK look more human regarding behaviour, elements analogous to those which people use to communicate will be provided, as it was mentioned before in section 2.3. This will make a big difference compared to the existing robots, dealing with expressiveness. None of the examples introduced have facial expressions close to that of a human. The more similar it is, the more useful TUK will be as an instrument able to teach kids how to express feelings to other children (with problems related to them). Using actuators, and after an analysis of how the facial muscles exert the forces to move the face features, is it hoped that natural grimaces may be performed. Through an initial study of the movements, the DOF can be set and the necessary number of motors implemented. The different mechanisms will be devised according to other concerns such as space, sturdiness and material limitations.

- Versatility: this is an issue of paramount importance. Nearly all the studies and theories have demonstrated that each autistic child responds differently to the therapies and treatments available to them [12][20]. On account of this, a versatile interactive robot such as TUK - which would be able to be adapted and customised to meet the personal requirements of each child - is a clear asset. This purpose will be achieved by the design, using materials and tools readily accessible to everyone. For instance, the 3D printer allows customisation of different elements. Moreover, the use of the open-source platform Arduino eases this concern. As the code available as well as the interface is easy-to-use, the programme that controls the expressiveness by TUK's movements can be directly modified and suited to each child's needs and preferences.

- Affordability: such an efficient and useful therapy should be introduced in every household. This aim can be reached through manufacturing and support from Arduino?s open-source hardware TUK.

In short, the development of this project aims to endow TUK with attributes lacked by the therapeutic robots that are currently. Nevertheless, these attributes are considered relevant in improving the results produced in the treatment of these behavioural disorders.

3 Methodology

3.1 Used concepts

As previously explained, TUK has to be able to express - using different mechanisms - emotions and feelings. Before devising these mechanisms, a review of (mainly) Paul Ekman's and Simon Baron-Cohen's literature was undertaken (domain expertises in facial expression and autism, respectively). The intention here was to fully discover how emotion should be portrayed and which aspects should be emphasised.

The feelings to be expressed are the six universal expressions, which are [10][21]:

- Happiness: symbolised by rising of the mouth corners and tightening of the eyelids;
- Sadness: symbolised by lowering of the mouth corners, the eyebrows descending and the eyelids dropping;
- Fear: expressed by the eyelids raising, eyes opening and the lips stretching horizontally;
- Surprise: symbolised by eyebrows arching, opening eyes and mouth, with the jaw dropping slightly;
- Anger: expressed by eyebrows lowering, lips pressing firmly and eyes bulging;
- Disgust: symbolised by the upper lip raising, nose bridge wrinkling and cheeks elevating.

3.2 Design methods

Every mechanism will be commanded by a microcontroller which will receive the input signal from the cameras in the eyes. This signal will be processed by the algorithm programmed in the image recognition software. It will allow for the identification of the emotions expressed by the child, regarding different features.

It has also been planned to implement software which analyses the input sound from built-in microphones to determine the children's feelings. In addition to this, the identification through physiological signals such as heart rate or skin temperature has also been researched, with intent to implement.

The output from all this software is considered to be the same: the emotion experienced by the child. Depending on the identified feeling, an output signal is sent from the microcontroller. This microcontroller controls the actuators integrated into eyes and eyelids in charge of TUK's animation. It will also control future mobile mouth, paws and wings, which are planned to be developed. The output signal gives different orders to the electromechanical components which then perform the expressions in a controllable and coordinated way.

3.3 Programming

To deal with the control of the servo motors, an Arduino Uno SMD Rev3 microcontroller board - based on the ATmega328 - has been used [22]. The Arduino software consists of an integrated development environment (IDE) and the core libraries. The IDE is a cross-platform application written in Java and based on the Wiring development environment, which is based on Processing as well. The core libraries are written in C and C++ and compiled using avr-gcc and AVR Libc. The source code for Arduino is now hosted on GitHub [23]. The code implemented for the right eyelid can be found in Appendix A.

The image recognition software has not been implemented yet in any microcontroller. On account of this fact, a switch is used to test and exhibit the movements associated with each emotion. By pressing it, the value of the variable ascribed to the different emotions ("expression") performs changes sequentially. These changes follow an order arbitrarily established, and that can be seen in the comments beside the code. In the final implementation, the actuators will get this input signal from the image recognition software, and the value of this variable will be assigned accordingly. The reading and connection of this switch involve some aspects explained in Appendix B.

Through this programme, making use of the Arduino outputs dedicated for PWM, the different motions are classified. For each of them, values to position both motors which control the sides of the eyelids are written. Each of these values indicates how many grades the servos have to turn to impel the desired location of the eyelid. The function that assigns the movements to each one of the pursued expressions is executed just inside the ISR. Thus, it does not run all the time, but only when the value of the variable "expression"changes using the switch.

An Arduino MEGA based on the ATmega2560 with 14 PWM dedicated outputs can also be used to directly connect with the 8 servos (2 per eyelid and 2 per eye). However, it has a higher price.

4 Design

In this section, the process of design of the different manufactured pieces which are part of this first prototype of TUK will be presented. These items are the **cameras**, which allow TUK to see; the **supporting structure**, which holds up the rest of the elements; the **eyes**, which cover the cameras making TUK look more human-like and friendly; and the **eyelids**, which provide eloquence and the expression of various emotions.

4.1 Cameras

The camera is a component that will play the role of the pupil from a human eye. That is to say, through the camera TUK will be able to see and the image received will be the input signal to the image recognition software, which will process it. Thus, the cameras have to yaw and pitch as eyes do. These movements consist of rotations around two perpendicular axes (providing two DOF). As well as this, the centre of these rotations is common and coincident with the sphere centre (similar to human eyes).

Each camera should move independently with two rotational DOF: the first one, **yaw**, around the perpendicular axis to the ground surface, allowing for the left-right motion; and the second one, **pitch**, to look up and down. To be able to move each eye independently, they cannot share any axis, and two motors need to provide each eye's movement. In this case, the eyes' position is not determined only by the different emotions, but with the field of vision required by the image recognition software for the cameras.

4.2 Supporting structure

Extensions from the base serve as supporting structures for the eyes, providing stability and firmness.

Space is required in TUK's belly to host sensors, actuators, PCBs, microphones and other electromechanical components which will aid further improvements. Cameras, eyes, eyelids and their mechanisms need to be fixed. Hence, an extension of the structure has been planned. Once the enlargement of the structure is settled, a long FFC cable is necessary, which communicates between the microprocessor placed in the lens and the microcontroller located on the PCB. The wires are then soldered so that they may be extended.

The first model of the extension is a circular tube with an upside down L shape. It is designed with the same diameter of the hole found in the original camera base to be placed on it. The extension is conceived hollow with the intention to hide and protect the wires, providing safety and insulation. The camera is screwed on forming 90°with the perpendicular axis to the ground surface to cover up the mechanisms (out of the children's reach and view). On account of this, the yaw of the camera is subject to an unimportant decrement. Figure 6 shows the structure designed in Tinkercad.

The eye cases are projected to have a large diameter, so the prior model for the structures clashes at the top part. Given this, the design has had to be changed as can be seen in Figure 7.

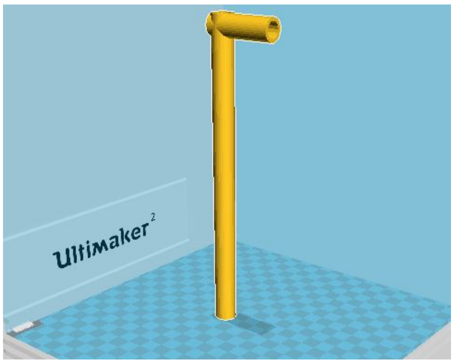


Figure 6: Extension by Tinkercad version 1

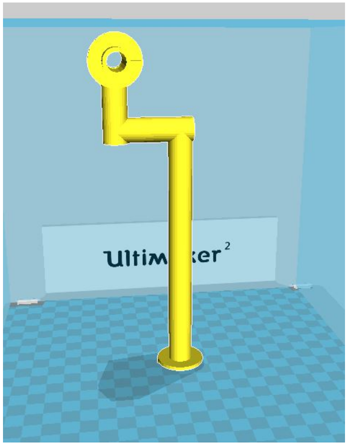


Figure 7: Extension by Tinkercad version 2

4.3 Eyes

As far as the layout is concerned, first of all, the movements are tested and the lens position planned. The lens is placed tilted slightly forward and downwards because of pitch range, which is larger as it goes upwards.

As a consequence of shifting one motor from the base, the eye case moves but not the supporting structure nor the connection piece, which remain. Thus, a hole backwards in the case is needed. Its dimensions need to be big enough to allow a notable range of the yaw and the pitch of the case without hitting the extension structure. Bearing this in mind, the handicap is the motors. There is no problem with the pitch movement since the only obstacle is the case itself. It is easily solved by measuring the height requirements for the hole. However, there is a problem with the yaw because the motors could hinder it and crash with the case and the connection piece.

Some other issues have to be taken into account. For instance, the eye case is split into two halves. To make it one piece impedes its dismantling. The original case which covers the camera has its halves divided vertically (right and left). In contrast, it is considered a better idea to make the cut along the horizontal line. This approach is based on two arguments:

- **Stability**. As the weight is leaning forward and downwards because the camera is tilted towards this direction, it is better not to make the division aligned with the junction, in order to increase steadiness.

- **Movement design**. It is planned that the motor which provides the yaw is located inside the case. Its draft is required to be placed in alignment with this rotational axis. On account of the fact that the movement transmission is stronger, easier and preferable to be made to a single half rather than to two, a joint in the connection area has to be avoided. As a result, this motor mentioned above has to transmit the rotation solely to the upper or lower part of the case, which forms an element of itself. Due to placement and operational concerns, the transmission element is placed attached to the upper half.

The process of joining these two halves together to make the case robust has been studied. Adding matched pairs of ribs to the inner surface has been considered. One possibility is a connection through a hole in one of the ribs from the pair and a cylinder extension attached to the other (see Figure 8). However, due to the layer printing technique used by the 3D printer, it cannot be adapted. Thus, the cylinder extension is discarded. According to the number of ribs, two pairs do not leave enough space for the internal components, so one pair is set.

Another detail to be created is the element attached to the motor shaft and the case in charge of the motion transmission. At an early stage, it is devised as a third element - a prism which surrounds the motor shaft and forms part of the eye case - as shown in Figure 8. Therefore, the torque increases in comparison to impel the movement directly. Nevertheless, it does not meet the requirements since the fewer pieces, the more fixed. Hence, a cylinder that comes down from the case itself and covers the shaft is planned. Inside it, a hole is designed with the dimensions of the motor shaft to utilise the maximum torque the motor supplies, which is of 34.3mN.m.

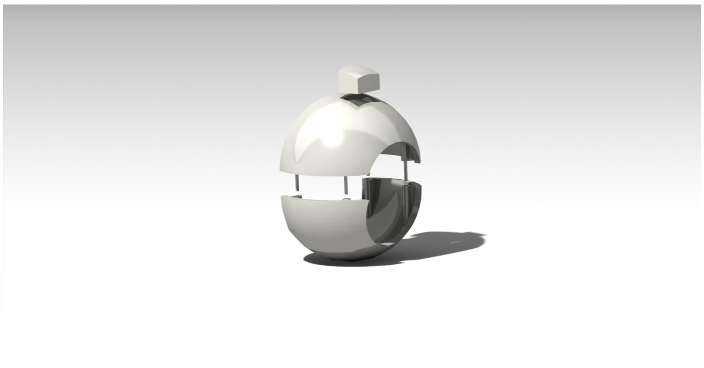


Figure 8: Eye case by CATIA version 1

On account of the fact that this design is more complex than the supporting structure one, Tinkercad does not meet the needs due to its simplicity. SketchUp shows problems providing thickness to the cases. AutoCad commonly used for two-dimensional designs is not as helpful with three-dimensional ones. However, CATIA, whose appearance could seem not as user-friendly, turns out to be the more useful and powerful tool here. Placement concerns and small problems with the little inaccuracy of the 3D printer are fixed and the model is shown in Figure 9.

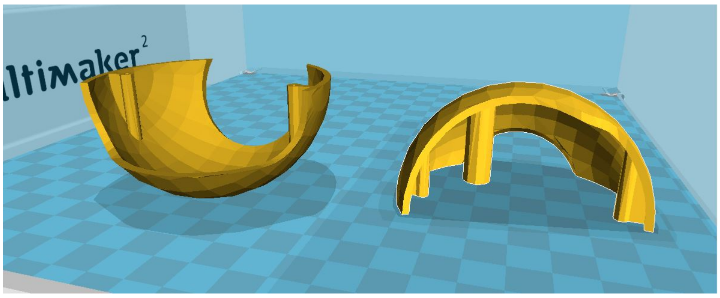


Figure 9: Eye case by CATIA version 2

4.4 Eyelids

The eyelids are in charge of the emotion expression by their animation.

4.4.1 Modelling

Humans are endowed with numerous facial muscles around the eyes - such as orbicular, corrugator, and procerus - to perform different emotions. In an attempt of bringing this to life, pitch and roll for the eyelids are allowed (two DOF). Thus, they can close and open, as well as tilt towards inside or outside. The model is designed with CATIA as shown in Figure 10.

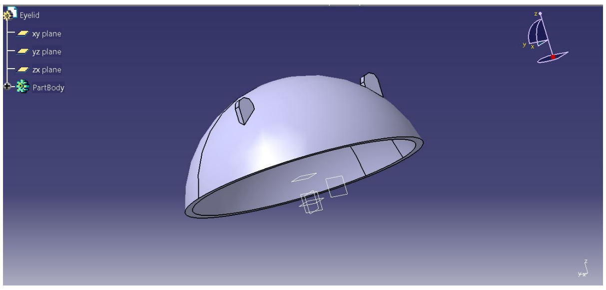


Figure 10: Eyelid by CATIA version 1

4.4.2 Mechanism

Regarding the mechanism to animate the eyelids, it allows movement around two perpendicular axes: the first one, **pitch**, to close and open; and the second one, **roll**, to tilt. That is to say, two DOF have to be empowered. These eyelids must be able to move independently, which gives TUK more expressiveness. Their position will depend on the emotion to be expressed.

The first approach to accomplish this is inspired by the internal mechanism of the first computer mice. The primary purpose of any mouse is to turn the motion of the mouse itself (namely the hand) into signals for the computer. The trackball mice are composed of a rubber or plastic ball which rolls when the mouse moves. Besides, two perpendicular rollers touch the ball, detecting X and Y motion. Each roller is connected to a shaft, which spins a disc whose position is sensed by an optical encoder. Then, the sensor pulses are read by an on-board processor chip. Finally, the chip sends these pulses to the computer [26]. An image where it is possible to observe this is shown in Figure 11. Nevertheless, applying this mechanism to the current concerns, the I/O have to be exchanged since instead of codifying the movement it is wanted to be impelled.

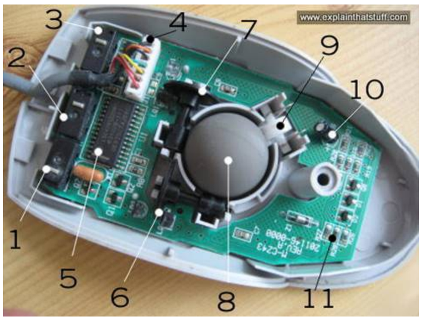


Figure 11: PC mice mechanism

By adding two rollers with the proper grip in contact with the eyelids, the movement can be boosted by friction. Bearing this in mind, the biggest problem is to control the motion. The mechanism in this way is an uncontrollable control system (an open-loop), since there is no information about the eyelid position to feedback and set up the desirable reference value. An additional problem is that the eyelid can move freely because there is no fastening element. Thus, knowing the motors state (as it is possible with servomotors) is not enough.

The feedback required to solve this matter and turn the mechanism into a controllable control system (close-loop) would be achieved by attaching a sensor. This sensor traces the location throughout the plane constituted by two spatial coordinates - variable of the eyelids' position to be monitored. This can be accomplished by an analogue grayscale sensor for the Arduino board. In addition to this, a 2D colour spectrum printed on the eyelid's surface is required to track the movements. One such example is shown in Figure 12.

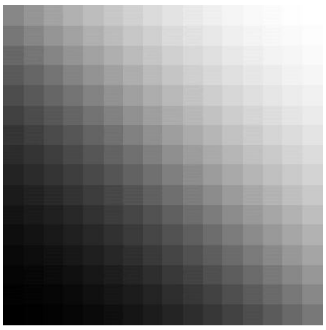


Figure 12: Grayscale matrix

On top of that, not all the problems are solved by just sensing the motion. Limits to prevent from free dislocation of the eyelids are requested. Otherwise, they could abandon the range of the servomotors (180°) and the control over them would be lost. Owing to this, blockages acting as limit switches have to be placed. Some of the solutions behold to impede the rolling are printed pieces or bumps over the eye case. It also has to be assured that even by pushing the eyelids, they do not get clogged.

The second approach, which has been implemented, is to drive the move to the outer sides of the eyelids. It is carried out by two arms powered by micro-servomotors, which transforms the rotational motion into translational. These pieces are connected by a loose joint adding itself one DOF and enabling movement in a perpendicular plane - and with it, the tilting. The representation of the eyelids assembled on the eyes and connected to this mechanism, can be seen in Figure 13.

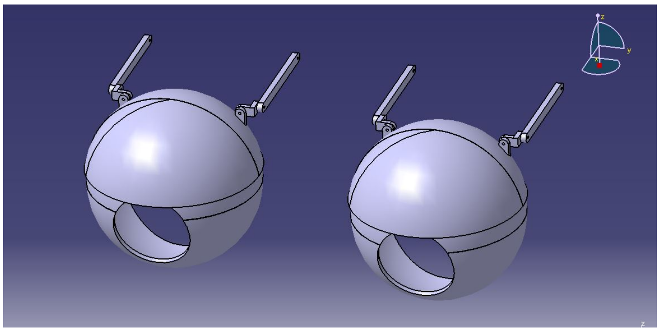


Figure 13: Ocular assembly

Three pieces joined by tiny screws compose each side of this symmetrical arrangement: **arms**, directly united to the shaft of the servos; **L-joints**, which share a loose joint with the arms and the small projection from the eyelid resembling ears; and **ears** coming from the top of the eyelid and attempting to be as hidden as possible behind to keep the mechanism out of the children's reach and view.

By this configuration, it is spared the necessity of adding a sensor because the position is controlled by the servomotors themselves. The coordinated motion can be monitored since these motors move with the eyelids also preventing them from detachment.

The problem that this arrangement presents comes along with the fact that it needs a coverage to guide the eyelids' movement. It can be a peak that comes out from the "egg", which covers the whole structure, or a large cap screwed to the top of the wood structure. This is not a problem itself; the problem arrives as the eyelid could get stacked with this element.

The increase of the eyes' diameter in the final implementation force the eyelids model to be changed. Apart from a greater size, a hole backwards is imperative to be made. Otherwise, the case hits the wood structure when turning. The CAD design can be seen in Figure 14.

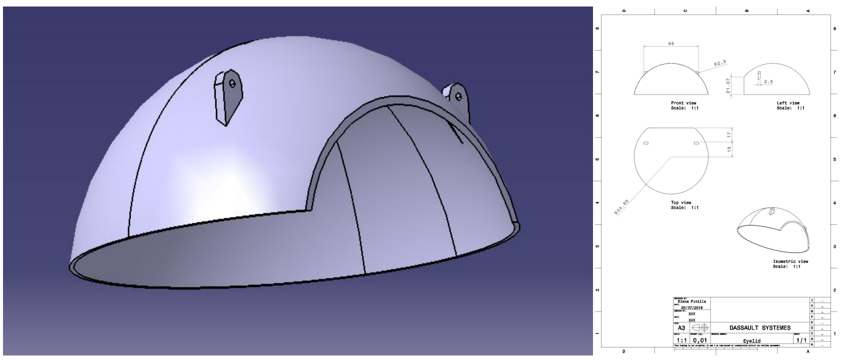


Figure 14: Eyelid by CATIA version Finale

5 Manufacturing and Implementation

After the design, decisions about manufacturing, the electromechanical components, the control system or problems found when assembling need to be made.

5.1 Cameras

As a first step in the implementation, the cameras have to be chosen. Among several alternatives, night vision and Wi-Fi capability over long-distance zoom are preferred. Hence, a Keekoon kk001 camera is acquired (see Appendix C).

Two stepper motors are already embedded inside the camera purchased allowing the two rotational DOF pursued. The technical specifications of the motors are in Appendix D. The motor that creates the pitch is located inside the camera sphere and the one that powers the yaw is set in the base case. This arrangement enables a yaw range of 345°(wider than the human performance) and a pitch range of 90°. Nevertheless, in TUK, a motor placed in the base force both eyes' supports and their top structures to turn around themselves. Therefore, both motors need to be within the eye case.

Consequently, the motors' size is a key factor. The built-in unipolar 4-phases stepper motors are bigger than desired. The image recognition software is in charge of the cameras motion and has not yet been implemented in any microcontroller. So that, the original camera software is kept to test the movements. Owing to this, just motors with the same control system, characteristics and connection can replace the former ones. However, the 24BYJ-48 are the smallest on the market that fulfil this.

Another possible alternative weighed up is to replace the steppers by servos. The reason is that servomotors offer as advantages smaller size and simpler control system. Nonetheless, the microcontroller, where the control system is programmed, has to be changed due to their different operation. Moreover, the connections cannot be modified when the chip is not made to order. Due to this, the PCB, where the pins for the components are placed, would have to be substituted as well.

A replacement for the inner piece, which surrounds the motor's shafts and provides stability, is necessary if servos are used. The proposal can be seen in Figure 15. The framework is formed by two linked pieces to have a controllable system since the two camera rotations are dependent. One is mounted on top of the other one, and just one of them is transmitting the movement to the case (the upper one). Since the top piece is moving together with the lower one, both motions are communicated by a single connection. This configuration is also used with the steppers. The holes of these designed pieces have the dimensions of the servos selected to impel the motion.

The image recognition software sends an output signal through the microcontroller where it is programmed to command the actuators. This micro will be integrated into a new PCB, where the connection of the motors has to be allowed. Nevertheless, as it is not at disposal this PCB to connect the servo motors, the steppers are kept. To reuse the original application software of the camera is possible for the image recognition system. This application, called IP Camera Search Tool, allows an easy control of the camera motion by Smartphone, tablet or PC via Wi-Fi or Ethernet.

Some of the most notable features of these stepper motors are their low price (about $5,00) - accomplishing the budget requirements - and their accuracy, which defines their typical applications. Moreover, they are 4-phases unipolar motors, which involve a manageable control.

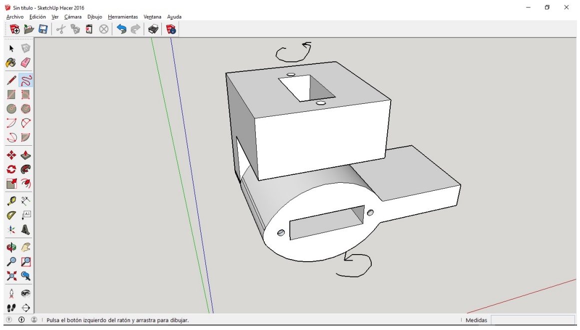


Figure 15: Optional new mechanism for the eyes by SketchUp

Unipolar stepper motors have a common wire to the power supply, as can be seen in the diagram in Figure 16. The other lines are connected to ground in a specific order to generate each step. In this case, the four coils have one pole in common.

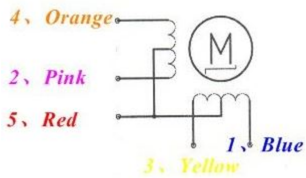


Figure 16: Stepper Diagram

5.2 Supporting structure

To manufacture the supporting structure, its compatibility with different materials is checked regarding strength, density and resistance to the tensions that the structure has to face (direction and magnitude).

The easiest way to fabricate it - as detailed as designed - is by using a 3D printer. Nevertheless, the **PLA** plastic used by the printer has low resistance to bending. Thus, the extension would be too large to support the required weight on it. Since motors, lens, eye case, eyelids and chip are not light enough; it is not feasible a support in PLA. [1]

Given this issue, aluminium and wood are considered as options. On the one hand, **aluminium** offers as an advantage the possibility to get it smoothly hollow to hide the wires. This material is light weight and moderately simple to work with. As well as this, it can be found easily. However, it is required a substantial base to compensate its light weight and stabilise the whole structure.

On the other hand, **wood** presents a lower density ($0'65g/cm^3$) than aluminium ($2'7g/cm^3$) [25], which adds more resistance against bending. Other advantages are that it is inexpensive, easy to find and to work with using simple tools. Therefore, wood is chosen. Two wood sticks are attached to a wood base and adapted. On top of them, the cameras, motors and mechanisms are screwed.

[1] Apart from this, another aspect that should be born in mind is that with PLA plastics, high-speed tools should not be used since they meld the pieces. When cutting or drilling, low speeds have to be used.

5.3 Eyes

Regarding the desired human characterization, two cases working as eyes are produced to represent the sclera. Pupils and iris are represented by the camera lens itself.

5.3.1 Material analysis

In the selection of the proper material for the implementation, the priorities are light weight, ease to be made to measure, and to manufacture. As well as this, it is the hardness against children's handling since it is an external element.

Large enough **ping-pong balls** are not available because they are just sold with standardised measures (40mm diameter), which are too small to host both motors and the camera. **EPS balls** are considered as well. The problem, this time, is to get them hollow with the proper size. Conversely, just too big EPS balls are sold empty. **EVA balls** - used in many toys - do not fulfil the demands as they are not sturdy enough to protect the electronic components from squeezing by children's hands. **PLA plastic** eye case is the best choice. It solves the previous problems and its manufacture is easy as a 3D printer is at disposal.

5.3.2 Set up

Once the model is manufactured, it continues the assembly. Both eyes' halves - attached by a proper glue - show a problem to be solved. The centre of the printed sphere cannot be placed coincident with the pitch axis defined by the motor, because of space constraints.

The sphere is designed to gather all the inner components but not with enough place to be reached the centre by the motor axis. In addition to this, the elements kept from the original camera hinder. These items come out from the wood structure and it is considered not necessary to remake them. As a result, it is achieved a rotational + translational motion, which goes against the procurement of human appearance pursued. To solve this, the eye case's diameter is increased. The last design can be seen in Figures 17 and 18.

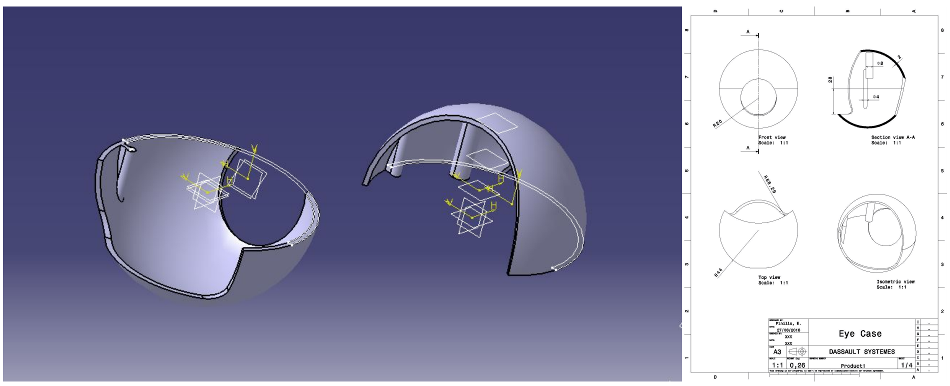


Figure 17: Eye case by CATIA version Finale

Figure 18: Eye Implementation

5.4 Eyelids

For the material to manufacture them, PLA is the election regarding the same reasons applied to the eye case material search.

First of all, it is considered the first approach to impel the movement to the eyelids: the friction mechanism. In this case, a paramount item which needs to be addressed is the selection of the material to cover the rollers. Each material has a different friction coefficient, which makes it more or less useful to the purpose by providing it with more or less grip to transmit the movement .

The second approach, which has been implemented, is to drive the move by two arms connected by a loose joint which adds itself one DOF enabling the eyelids to roll. The loose of the joints is achieved by making wide holes where the screws are placed.

5.4.1 Electromechanical Components

Both approaches for the mechanism share the idea of setting backwards the two necessary motors per eyelid hidden from the outside reach and view.

The characteristics of the servomotors chosen to accomplish this can be seen in Appendix E. The main reason of their election is their tiny size (19.7x8.2x24 mm), which provides more space where this is the greatest limitation. However, the factor that needs always to be evaluated when a motor is to be chosen, it is the torque - the tendency of force to rotate an object about an axis, fulcrum, or pivot. Two servos with a torque of 5Ncm and a devised rotation with a radius of 1.5cm imply that the weight the servos can support is of 0.68kg, by:

$$2 \times 5Ncm = 0.68kg \times 9.8ms^2 \times 1.5cm$$

This fulfils the conditions of this mechanism perfectly.

Another significant advantage of using servomotors is the simple control system they require. A servomotor is a closed-loop servomechanism which uses position feedback to control its motion and final position. This is thanks to a built-in sensor, regularly an encoder. The input to its control is a signal, analogue or digital, representing the position commanded for the output shaft.

The control of servomotors is made by a PWM signal, which is a series of repeating pulses of variable width. The angle of the rotation is determined by the width of the electrical pulse that is applied to the control wire (servomotors have three wires: power, ground, and control). This defines how far the motor turns. However, servo position is not determined by the PWM duty cycle (ON-OFF time), but by the width of the pulse.

The Arduino board, which controls the servos, has some specific outputs dedicated to PWM control and the proper signal is sent by writing in the correspondent function from the Java library. It was already introduced in section 3.3, as well as the code is shown in Appendix A.

5.4.2 Performance

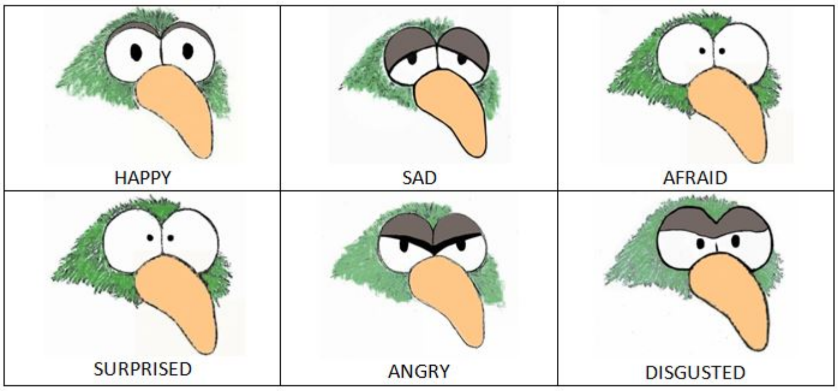


Figure 19: Expressive TUK

The intended eyelids motions to represent the emotions can be seen in Figure 19, which are:

- Happiness: both eyelids up, showing the whole eye;
- Sadness: eyelids slightly down, covering approximately half of the eye and tilting towards the outside;
- Fear: eyelids completely open;
- Surprise: eyelids as well completely open;
- Anger: eyelids slightly down, covering approximately half of the eye and tilting now towards the inside;
- Disgust: eyelids at a medium position.

6 Conclusion

6.1 Summary

TUK aims to be a robotised stuffed animal encouraged to become a companion aid tool for social therapy of autistic children. The work during this thesis was done to provide TUK with animated eyes and eyelids to perform different emotions by its movements. The input to the control system comes from the image recognition software. Then, regarding the emotion, a different output signal is sent to the actuators which are in charge of moving the elements of the mechanisms.

Not only the control system programmed in an Arduino board, but also the communications to make everything works and the mechanisms devised to allow the necessary DOF, have been carried out. Moreover, the pieces (eyes, eyelids, supports...) have been measured, designed and manufactured to achieve the mechanical conditions.

The eyes' models have been completed and implemented, as well as the appropriate positioning of the motors to allow independent yaw and pitch (two DOF = two motors per eye). Thus, the eyes are capable of performing the required movements to fulfil the image recognition's demands.

The initial models of the eyelids have been done as well. However, according to the last model of the eyes, the proper ones have not been implemented. The last required changes have been included in the CAD designs but not printed yet. Through the mechanism devised, these eyelids can pitch and roll independently (two DOF per eyelid). The program implemented in the Arduino board, which controls the servomotors that impel the movement to these eyelids, is ready to move them in response to the emotion identified.

The used tools to accomplish these tasks have been CAD software, a 3D printer, and the appropriate tools to drill, solder, measure, saw and assembly, among others.

Since TUK is children-oriented, it has to be robust, safe and appealing. These factors have implied limitations during the process, and it is necessary to keep them in mind.

6.2 Future work

First of all, it has to be mentioned that all the tests and elements implemented have been applied to one eye. However, all the designs, models, and assemblies can be duplicated and set equally to the second one.

One of the issues to be covered here would be the manufacturing of a new piece to host the rotational axis of the camera, as it was presented in Section 4.1.2. The advantage of this new approach above the others is that it requires a smaller diameter for the eye case. Nevertheless, it is designed for the size of micro servomotors, and not for steppers' volume. Therefore, the software of the camera acquired should be dispensed with due to the PWM control system required by the servos. As well as this, a second micro-controller or a bigger one is are needed to manage with all the motors.

Another open issue that has been previously discussed has to do with the eyelids mechanism. It was introduced as the first approach to transmit the motion to these elements by friction.

Apart from the rollers in charge of this transmission, sensors will be necessary to have control over the eyelids' position. The image that clarifies this concept can be seen in Figure 11. As well as this, in Figure 12 can be found a sketch of the pattern that it is required to be attached to the eyelid surface if the sensors are grayscale sensors. This pattern allows the codification of the location along both X-Y axis - compulsory as each eyelid has two DOF.

6.3 Further Expansions

The planned future work is mainly concerned with making TUK more expressive since this is a fundamental goal of this project. However, some other key issues have been taken into account, such as additional elements to interact with children or set the requisites to adjust TUK to the correspondent regulation.

6.3.1 Mouth

Apart from eyes and eyelids, the mouth is considered one of the most expressive facial features. Facial muscles as the zygomaticus, the risorius or the depressor, for instance, exert forces to move lips and the corners of the mouth to communicate feelings physically.

The different movements that could be provided, sort by emotions, are:

- Happiness: a smile would be shown by positioning the corners at the extremes of the range of motion and they would be forced up. The mouth-lips would be held together and the tongue horizontally moved (extra mechanism);
- Sadness: mouth closed and corners forced down at the extremes;
- Fear: the mouth would open and close like chattering by moving the centre;
- Surprise: mouth opened (from the centre) and corners at the minimum range of motion;
- Anger: mouth closed and corners at the extremes at medium height;
- Disgust: upper lip raised while maintaining the lower neutral, as well as the corners down.

6.3.2 Sound

It has been previously mentioned in Section 3.2 that apart from the way of identifying emotions by image recognition, there are developed techniques which do this through sounds. In this case, the trigger to command the actuators through the microcontroller would be the input signal it receives from microphones.

Moreover, another matter dealing with the emotion expression covered in this report is the possibility of making sounds instead of receiving them. The sound could be implemented in TUK with hidden and small speakers to complement the representation of the emotions. Tunes according to each state and the feeling that it creates, could be played while TUK moves. However, some children with autism are sensitive to hard or sharp sounds. So that, the melodies played must be preferably classical [27].

6.3.3 Other Features

Allowing a remote control could be interesting and useful. In the meantime, a game app could be developed to help autistic kids overcome the fear of daily routines by rewarding them with virtual prizes (the idea was taken from Popchilla [14]). This application could also allow the child to identify TUK's emotions himself. It could be even possible to communicate with TUK, who would answer. More educational apps could be also programmed and added.

TUK behaviour could be customised as well. While working with children with autism, it is claimed that some respond well to robots while others do not. A computer program could recognise within seconds whether or not the child has a positive interaction. This early-detection system could be used in the future to turn any number of TUK features on or off depending on how a person responds to them [12].

6.3.4 European Toy Safety Directive 2009/48/EC

The rules established by this regulation need to be objectified in this project to make it realisable and have a real chance to be used for the foreseen purpose.

Children's security should always be kept in mind. The use of safe pieces and non-toxic materials is a basic for the design. Since moving and small pieces are needed, they will be forced to be properly attached in order not to cause any injury.

References

[1] Scott M. Myers and Chris Plauché Johnson. Management of children with autism spectrum disorders. *Pediatrics*, 120, 2007.

[2] Susan E. Levy, David S. Mandell, and Robert T. Schultz. Autism. *The Lancet*, 374, November 2009.

[3] Chris Plauché Johnson and Scott M. Myers. Identification and evaluation of children with autism spectrum disorders. *Pediatrics*, 2007, November 2007.

[4] Autism Speaks. The triumph of partnership. https://www.autismspeaks.org, 2014.

[5] Marian Sigman and Angeline Dijamco. Identification and evaluation of children with autism spectrum disorders. *Pediatrics*, 2007, November 2007.

[6] Ami Klin and J. McPartland. Asperger's syndrome. *Adolesc Med Clin*, 17(3), Octuber 2006.

[7] Empathy. *Encyclopaedia Britannica*. Encyclopaedia Britannica Editorial, 15th edition, 2010.

[8] Simon Baron-Cohen, Ofer Golan, and Emma Ashwin. Can emotion recognition be taught to children with autism spectrum conditions? *Proceedings of the Royal Society*, 364(3567), 2009.

[9] Simon Baron-Cohen. The empathizing-systemizing theory of autism: Implications for education. *Tizard Learning Disability Review*, 14(4), 2009.

[10] Paul Ekman. *Emotions Revealed, Second Edition: Recognizing Faces and Feelings to Improve Communication and Emotional Life*. March 2007.

[11] Bernardo Ronquillo. Cómo un robot social puede estimular un niño con autismo. *Intelligent Observer*, September 2015.

[12] Kirsten Weir. Robo therapy. *American Psychological Association*, 46(6), June 2015.

[13] Robot U.S., Inc. Paro therapeutic robot. http://www.parorobots.com, 2014.

[14] Interbots, LLC. Popchilla's world: A game for kids with autism. http://www.popchillasworld.com/, 2012.

[15] Malia Spencer. Popchilla finds purpose in dealing with autism. *Pittsburgh Business Times*, October 2011.

[16] Anita Hamilton. Can robots help autistic kids connect? *http://www.fastcoexist.com/*, September 2012.

[17] Beatbots, LLC. My keepon - official site. http://www.mykeepon.com/, 2016.

[18] Aldebaran Robotics. *NAO Robot + ASK NAO tool*.

[19] Brodie Beta. Five therapy robots helping with alzheimer's, autism and cancer. *http://geekbeat.tv/therapyrobots/*, October 2010.

[20] Autism Speaks. How is autism treated? https://www.autismspeaks.org/what-autism/treatment.

[21] Cole Calistra. The universally recognized facial expressions of emotion. *Kairos*, March 2015.

[22] Atmel Corporation. *ATmega48A/PA/88A/PA/168A/PA/328/P*, 2015.

[23] Google Code. https://code.google.com/archive/p/arduino/, June 2016.

[24] Texas Instruments. *TLC5940 16-Channel LED Driver With DOT Correction and Grayscale PWM Control*, 2015.

[25] Density of some common substances. Consulted on 21st June 2016. URL: http://educatoral.com/density_of_substances.html.

[26] Marshall Brain and Carmen Carmack. How computer mice work. *How stuff works - TECH*, April 2000.

[27] Autism Speaks. Autism & anxiety: Parents seek help for extreme reaction to loud noise. https://www.autismspeaks.org.

A Arduino code to control the right eyelid

```
/* RightEyelid by Elena Pinilla Sediles June 2016 */

#include <Servo.h>

Servo REyelidL; //create servo object to control the servo
                that moves the left part of the eyelid
Servo REyelidR; //create servo object to control the servo
                that moves the right part of the eyelid

int posL = 0;  //variable to store the left servo position
int posR = 0;  //variable to store the right servo position

const int timeThreshold = 150;   //Value of ms set as
                                 threshold to deal with the
                                 noise in interruptions

const int intPin = 2;   //Pin where the switch is connected

volatile int ISRCounter = 0;    //Counters to implement
                                the debounce by software
int counter = 0;
long timeCounter = 0;

volatile int expression = 0;  //do something different depending
                              on the expression value, according to:
                              // 0 -> eyes closed -> sadness
                              // 1 -> eye opened -> happiness
                              // 2 -> eye wide opened -> suprise
                              // 3 -> extreme tilt left-inside
                                   (right eyelid) -> anger
                              // 4 -> eye right opened -> disgust
                                 (the left one will be closed)

void setup() {
        Serial.begin(9600);   //initialize serial communication:
        pinMode(intPin, INPUT);    //Pin where the switch is
                                   connected declared as
                                   input and pull-up
                                   resistance external
        attachInterrupt(digitalPinToInterrupt(intPin),
        debounceCount, FALLING);   //Translates the switch pin
                                   to the specific interrupt
                                   number; ISR=debounceCount;
                                   triggered with the
                                   falling edge
```

```
        REyelidL.attach(11);    //attaches the servo on pin 9
                                to the servo object left
        REyelidR.attach(10);    //attaches the servo on pin 10
                                to the servo object right
}

void loop() {

        if (counter != ISRCounter){    //the counter is checked
                                   and if it has changed,
                                       it is increased
                counter = ISRCounter;
        }
}

void debounceCount(){          //ISR
        if (millis() > timeCounter + timeThreshold){
                ISRCounter++;
                timeCounter = millis();
                changeExpression();    //the value of the
                                       "expression" variable
                                       changes when an
                                       interruption occurs
        }
}

void changeExpression(){
        expression ++;     //each time the switch is pressed
                           (exits interruption), the
                           "expression" increases
        if (expression == 5){     //when the value of 5 is
                                  reached after the
                                  increasing, "expression"
                                  has to come back to 0
                expression = 0;
        }
        switch (expression) {

                case 0:     // sadness 90-90
                        posL = 90; //left servo to 90 degrees
                        posR = 90; //right servo to 90 degrees
                        REyelidL.write(posL); //tells servo to
                                              go to position
                                              in variable 'pos'

                        REyelidR.write(posR);
                        delay(15);  //waits 15ms for the servo
                                    to reach the position
```

```
                    break;

        case 1:     //happiness 145-45
            posL = 145;
            posR = 45;
            REyelidL.write(posL);
            REyelidR.write(posR);
            delay(15);
            break;

        case 2:     //fear 180-0
            posL = 180;
            posR = 0;
            REyelidL.write(posL);
            REyelidR.write(posR);
            delay(15);
            break;

        case 3:     //suprise 180-0
            posL = 180;
            posR = 0;
            REyelidL.write(posL);
            REyelidR.write(posR);
            delay(15);
            break;

        case 4:     //anger 180-180
            posL = 180;
            posR = 180;
            REyelidL.write(posL);
            REyelidR.write(posR);
            delay(15);
            break;

        case 5:     //disgust 180-90
            posL = 180;
            posR = 90;
            REyelidL.write(posL);
            REyelidR.write(posR);
            delay(15);
            break;
    }delay(1);  //delay in between reads for stability
}
```

B Switch program

To read the digital input it has been chosen to be done as an interruption. The reason of this is to avoid reading the input signal recurrently with a delay between inquiries to track down a change in status. This mechanism known as “poll”, has as main disadvantage that it continuously consumes processor time as well as energy waiting for the inquiry to be intolerable. Moreover, if the pulse is too short and the processor is busy, it could be missed.

For all this, to read the switch input as an interruption is the best idea. Firstly, it is associated a function to the occurrence of a particular event, called ISR. In Arduino, the interruptions can come from timers or from hardware (pins). This last one is here applied, linking interruptions to pin 2, where the switch is connected. The event detected is a FALLING (falling edge), from HIGH to LOW.

In this case, the ISR leaves the normal program flow. Then, it is executed and goes back to the main loop exactly at the interruption point. It just calls a secondary function (“change-Expression()”) which changes the value of the variable associated with the different emotions expressed (“expression”). Afterwards, this variable is attended in the main loop. It is declared as “volatile”to be able to be modified inside the ISR. The keyword “volatile”indicates the compiler that the variable has to be checked before its use because it could have been modified out of the main loop (what precisely makes an interruption).

To define an interruption, it is used “attachInterrupt(digitalPinToInterrupt(pin), ISR, mode)”, where “digitalPinToInterrupt()”converts a pin into an equivalent interruption. This enables the exchange of the model of the circuit board without changing the code.

This switch is just a way to show how the different emotions are performed. However, as interruptions from a physical device are used, noise is generated when the device changes its status. In Figure 20, this effect from a switch can be appreciated. This phenomenon is known as “rebound”and it causes numerous trigger events. For this reason, it needs to be eliminated not to interfere in the interruption management, through a process called “debounce”. It can be done by software or hardware.

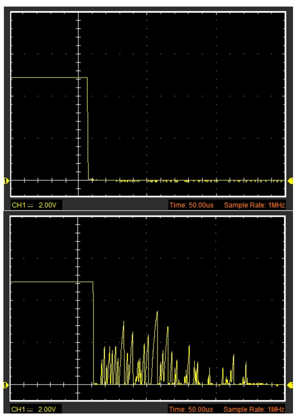


Figure 20: Falling edge without and with noise

The debounce by software has the advantage of requiring no additional components - the rebound is solved just by editing the code. As a disadvantage, it increases slightly the execution time and the complexity of the code. The most straightforward way of dealing with the interruptions is by verifying the time between trigger events of the interruption. If the time is below a particular time interval (threshold), the interruption is ignored. In other words, this interval would be a defined dead band, which is set by the variable “timeThreshold”and here is set as 150 ms. This value depends on the triggered component.

Another fact to be taken into account when dealing with a switch is the circuit to read its status. Pull-down or Pull-up resistors are essential. Here, a Pull-down resistor is chosen so as to read a HIGH (5 V) value when the switch is closed, as can be seen in Figure 21.

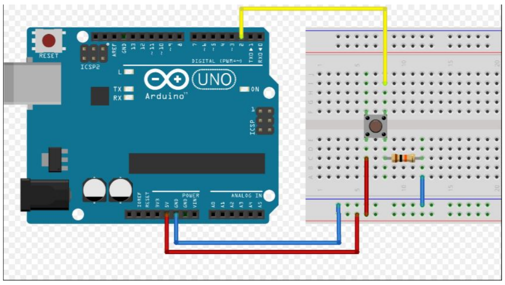


Figure 21: Pull-down resistor diagram

This configuration avoids an issue known as high-impedance state. It could have been connected the digital pin directly to a reference voltage through the switch and it would have worked when it is closed but not when it is opened. Arduino is programmed to either deal with HIGH, LOW (0 V) readings or edges resulting from them, coming in from the pin. Nevertheless, in an open case, the pin would be disconnected from any voltage. The read value then will be uncertain. This is because there is some electricity on the wire which can confuse the reading on the digital pin. The pin will be in a so-called floating state, between HIGH and LOW. Therefore, it should be avoided.

A solution to this would be to provide a way for the electricity to flow away to ground, without allowing a short-circuit when you press down the button (if it would be connected directly to two different voltages levels toggling according to the switch). A short-circuit would cause a high current and a fast heating of the components and conductors. By a 10kΩ pull-down resistor, it is forced the reading to ground when the button is not pressed.

To calculate the minimum value for this resistor to ensure the low status, the Ohm’s law is applied. It is employed a supply voltage of 5V and the maximum input current, 40mA.

$$R = V_{in}/|I_{in}| = 5V/40mA = 125\Omega$$

A 1kΩ resistor will be used, as the following standardised value, which has the advantage to be a cheap component and very easy to get. This is a widespread resistor value for this type of connections.

Arduino has internal pull-up resistors of 20kΩ but they are not often used because their value is too high and they are not properly set. They will cause a short-circuit.

C Keekoon KK001 Camera

http://www.keekoonvision.com/kk001

Description

KK001 features high definition 1280 x 720p video resolution, h.264 video compression, built-in DVR via SD card (up to 32GB), two-way audio, Wi-Fi capability, pan/tilt, remote internet viewing, motion detection, night vision as well as network video recording capability. In addition, it is Smartphone compatible (iPhone, Android - app required) as well as viewable over the internet using standard browsers on PC (Firefox, IE & Chrome) or Mac (Safari only). The camera functions well as a Smartphone baby, pet or elderly parent monitor or as part of a complete home/office security system with remote internet monitoring ability.

No matter where you are, stay connected to your favourite places, people and pets any time. Stream HD quality video and audio directly to your PC (Windows & Mac), iPhone, Android, or Tablet.

Feature

1) 1.0 Megapixel HD Pan/Tilt Wired/Wireless IP Camera;

2) H.264 Video Compression;

3) 1/4 inch color CMOS sensor (1 Megapixels);

4) P2P/PNP (Plug and Play) Technology (support QR cord scanning to view, without any complicated IP address setting, port mapping and DDNS settings);

5) Wi-Fi standards IEEE 802.11b/g/n (wired connection also included);

6) Two Ways Audio (built-in microphone and speaker);

7) Pan/Tilt Control (Pan: 345 degree / Tilt: 90 degree);

8) IR Cut-off Filter for true colour (no color cast);

9) Night Vision (up to 10 meters) via auto IR-LED illumination;

10) Infrared Motion Detection (with email notification and image upload via FTP);

11) SD Card Slot (support max storage 32G SD card for video and picture;

12) Support PC (Windows, Mac), Tablet (iPad, Android), Smartphone (iOS, Android) to surveillance and control from anywhere anytime;

13) Supports IE 8 or above, Safari, Firefox, Google Chrome and any other standard browsers to view;

14) Support image full screen and image snapshot;

15) Multi-level users's management and passwords definition;

16) Multi-Protocol support and Transportation (such as TCP, IP, SMTP, HTTP and etc);

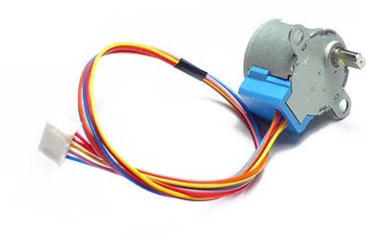
17) Support WEP/ WPA/ WPA2 Encryption.

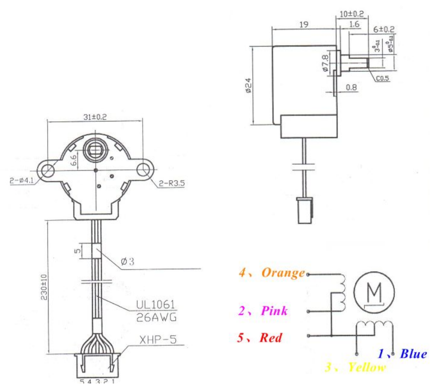
D 24BYJ-48 High Quality Stepper Motor 5V

http://www.emartee.com/product/41426/

Description

Rated voltage: 5VDC
Number of Phase: 4
Speed Variation Ratio: 1/64
Stride Angle: 5.625° /64
Frequency: 100Hz
Idle In-traction: 300Hz
Idle Out-traction: 500Hz
In-traction Torque: >34.3mN.m(120Hz)
Self-positioning Torque: >34.3mN.m
Friction torque: 800-1300 gf.cm
Pull in torque: ≥350 gf.cm
Insulated resistance: >1MΩ(500V)
Insulated electricity power: 600VAC/1mA/1s
Insulation grade: A
Rise in Temperature <55K(120Hz)
Noise <35dB (120Hz, No load, 10cm)





E Modelcraft Micro Servo ES-07 JR

https://www.conrad.de/de/modelcraft-micro-servo-es-07-analog-servo-getriebe-material-kunststoff-stecksystem-jr-231647.html

Description

The Modelcraft ES-07 JR micro servo should be a must for any serious model maker, either as a spare servo for your model or as part of the basic equipment of a hobbyist workshop.

Technical data

Weight	4.4 g
Gear box	Plastic
Type of bearing	Plain bearing
Servo technology	Analogue servo
Category	Micro servo
Connector system	JR
Actuation time at 4.8 V	0,09 s (60°)
Manufacturer part No.	ES-07 JR
Length	19.7 mm
Width	8.2 mm
Servo torque (4.8 V)	5 Ncm
Intended use	Spare part
Height	24 mm