Construction of a zoomorphical robot for rehabilitation of autistic children

K Niderla\textsuperscript{1,2} and M Maciejewski\textsuperscript{1,3}

\textsuperscript{1} Dream-Art sp. z o.o., Capital Park, Rejtana Rzeszów, Poland
\textsuperscript{2} University of Economics and Innovation, Lublin, Poland
\textsuperscript{3} Lublin University of Technology, Lublin, Poland

e-mail: konrad.niderla@netrix.com.pl; m.maciejewski@pollub.pl

Abstract. This article details the construction of a zoomorphical robot for use in therapy of children with Autism Spectrum Disorder (ASD). The robot was designed to act as a proxy in communication between a therapist and the child. It is made to look like a safe, rabbit-shaped toy to invoke feelings of warmth, safety and trust. Two versions of the robot were constructed. Laser cutting and 3d printing were used to construct the mechanical parts of the robots. Multiple movable joints allowed for easy conveying of emotions. The robot uses an LCD touchscreen to display a rabbit face that can be animated to simulate speech. Communication is possible via a camera, microphone and speakers. A specialized controller and control systems were designed to operate the robot. The devices are currently included in ongoing trials under supervision by trained specialists.

1. Introduction
Autism Spectrum Disorder (ASD) is referred to as a civilization disease. In the 80’s autism affected 1 in 2500 citizens, currently autism affects from 1 to 3 percent of population [1]. Autism can be defined as deficits in social communication and interaction and presence of restricted, repetitive patterns of behaviours or interests [2]. This is a problem not only for sick people but for their entire families. This paper presents the zoomorphically robot for rehabilitation of young patients. The robot was tested during clinical trials, giving satisfactory results in the most studied cases. Excessive stimuli, facial expressions and expression can be anxious and difficult to interpret for people with autism. The robot has simplified gestures and facial expressions, making it easier for autistic children to interact with the robot rather than with caregivers or other children [3-6]. Children with autism eagerly interact with the robot, make contact, often going beyond the limits that they do not cross when interacting with other people. The concept is presented in figure 1.

2. Robot appearance
The robot was designed as a zoomorphic toy enabling interaction with children. The device has some features of a rabbit and a human. Thanks to this combination it captures the interest of the youngest patients. Figure 2 presents the first version of the device in natural environment. The robot has a height of about 60cm, the size of the base is about 40cm by 30cm and its weight is about 5kg. The outer casing was made in the form of a fluffy fur in grey colour. The characteristic feature are rabbit ears and tail. The shape and appearance of the robot were consulted with psychologists and psychiatrists, specialists
in the field of rehabilitation of autistic children. The robot was made to feel soft, warm and safe and seem like a stuffed animal. It uses an LCD screen, speakers, a microphone and two cameras to communicate with the environment. The second version in figure 3 has sleeker, hairless outer casing made of polished and lacquered plastic, is taller and is made to look more robot-like and futuristic.

Figure 1. The idea of communication by a robotic proxy.

Figure 2. First version of the robot

Figure 3. Second version of the robot
3. Robot construction
The insides were made using 3D printing technology and laser cutting. The main mechanical subassemblies of the device are chassis, arms, neck and head. The whole robot body is covered by synthetic fur. A dedicated controller was designed to operate the robot’s drives and sensors. An isometric view on the inner workings of the robots can be seen in figure 4 and 5.

3.1. Chassis
The chassis skeleton is made of three main parts made of laser cut acrylic sheet. The parts are connected by elements printed from PLA. The chassis uses two drives in the front with a sliding pad at the rear, allows the device to move forward and backward, as well as turns and rotate around its axis. The drives use DC motors with a wide range of supply voltages and mechanical transmission based on a helical gearbox. Optical ground sensors are placed in the chassis, thus protecting the robot from falling from a great height, for example a table, a bench or stairs. The robot can easily move on smooth surfaces. Due to differentially driven motors it is possible for the robot to turn in place, move forward and backward, turn left or right and perform a combination of these moves. The rear end of the robot includes a small servo to drive the tail up and down.

3.2. Arms
Arms are made of printed parts connected by cyanoacrylic glue, screws and metal rods. They are driven using servo-motors mounted in the robot’s body. The force between the servos and joints is transferred by means of steel cables sliding in Teflon tubes. Such solution results in slim, light and slightly flexible arms. In the first version the arms have four degrees of freedom. They can rise up and down, lean back and forward in the shoulders, bend at the elbows and clamp and open the grippers. The paws allow use of light toys with small dimensions when playing with children. In the second version the arms can move up or down.

3.3. Head and neck
The head assembly additionally includes stereo speakers, a microphone, a camera and a capacitive 800x480px 5 inch touchscreen that acts like the robot’s face (figure 6). The robot head in the first version rotates left and right, tilts forward and backward as well as tilts to the right and left, giving it three dimensions of movement similar to a human head. Due to a wide range of motions the robot can nod for “yes”, rotate left and right for “no”, can display curiosity by tilting its face to the left or right or show sadness by lowering its head. Both sides of the first version’s head mount robotic ears, which can rotate in two axes front to back and side to side, therefore it is a remarkable tool to strengthen the conveying
of emotions to the patient. They can be used to show fear by lying flat, interest by standing up and joy
by waving up and down. In the second version the neck can rotate left and right and the ears can move
forward and back. The ears are made of springy material to seem more natural and safe.

Figure 6. Placement of sensors and main mechanical parts in versions 1 and 2.

Figure 7. Overall architecture of the onboard control system.

3.4. Outer casing
The first version is covered by synthetic fur. The pieces are and sewn together. Zippers that allow easier
 cleaning and access to inner mechanisms are hidden behind the ears and on the back of the robot. The
fur was chosen based on the opinions of experts in the field of treating children with behavioural
disorders [7]. The fur is grey due to the fact, that some children can find brighter and more pronounced
colours too captivating, unpleasant or triggering. The second version was made to look sleek, shiny and
more futuristic to seem similar to the modern concept of robots in children cartoons.

3.5. Dedicated controller
Actuators and sensors are connected to the controller designed especially for the application. The low-
level driver utilizes an 8-bit microcontroller ATmega2560 [8]. It is working with a clock frequency of
16MHz. Both motors are driven by two H-bridge modules MD10C. The servos are controlled by a
dedicated PWM multiplexing generator TLC5940 [9]. The controller can drive 18 axes independently
and with varying speeds, allowing for simultaneous movement of limbs, head, ears and tail. This
functionality can be used to express emotions and communicate using changes in posture. Variation of
speed in analogue servos was achieved by dividing the motion into a set of small changes in position
until target position is reached. Those changes in position are triggered by an internal clock interrupt.
Orders are received from the control system via UART/USB connection and the format is compatible
with JSON [10]. Due to fast response time it is possible to perform multiple varying actions
simultaneously, resulting in fluent motions of the limbs, head, ears, tail, fast response to sensors and
overall positive impression of the robot behaviour.
4. Control system
The distributed robot management system consists of an on-board Raspberry Pi computer, supervisory and control applications, and artificial intelligence services (figure 7). On-board computer located in the device manages motion, audio and video subsystems, as well as communication with the application supervising the operation of the device via WiFi network. The task of the surveillance application is to enable the operator to control and issue commands, as well as to mediate between artificial intelligence services and the on-board computer itself. Artificial intelligence services are responsible for processing the incoming audio stream into text transcription and then detecting the meaning of recognized sentences and words, detecting the characteristic elements in the video stream of the robot, e.g. patient recognition, emotion recognition, detection of toys and other objects in the environment. Artificial intelligence also receives messages and confirmations about actions performed (movement, movements). Based on the above data, artificial intelligence systems infer and recommend the next actions performed by the robot such as verbal responses, movements, displacement, emotions. Additionally, the operator/specialist is presented with a set of multiple predefined scenarios and sets of robot motions including dancing and singing and can invoke these events at will. Video and audio are also transmitted to the operator station on-line, which allows for direct supervision. Also, the operator can talk to the child using a microphone and sound is then emitted through the onboard speakers mounted in the head.

5. Clinical trials
The overall response of the children and staff interacting with and using the robots is very positive. Clinical trials are conducted at two centres dealing with the rehabilitation of autistic children. Currently, a group of 20 small patients has been examined, among which there are both boys and girls. Each study consisted of several sessions carried out on different dates. The first phase is to introduce the child to the robot, talk freely and play. The second phase of the study involved the implementation of a scenario in the form of conversation and playtime, displaying children’s cognitive abilities. In the third phase, the scenario is implemented without the robot, only in interaction with the supervisor.

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