# Treatments of Children with Autism Spectrum Disorders Using a Spherical Robot with Facial Expressions

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**Abstract:** Autism Spectrum Disorder (ASD) is a condition in many children, which referred to a broad set of behavioral disorders. Typically, children with ASD cannot communicate and interact with people, and as a result, having no social activities at all. Fortunately, they can interact with non-human object such as robots. There are hence many researches to treat these children using different shapes and types of robot. This paper investigates the effects of the spherical robot with facial expressions and movements in treating children with ASD. The designs, both structural and system, and suitable features of robot are studied and proposed. The preliminary experiments show impressive results that the proposed designs and features of the robot can successfully draw attention from 75% of the patients with different levels of disorders. However, more cases should be experimented in order to get more suitable details for treating ASD patients.

*Keywords*-- **Autism Spectrum Disorder, Spherical Robot, Embedded System**

## 1. Introduction

Robots have been proven to be useful in many areas of work including in medical therapy. There are several researches exploring the use of robot in therapy such as treatment for individual patients with Autism Spectrum Disorder (ASD) since the robot can be programmed to offer tremendous possibilities for innovation in treatments [1][2]. Typically, ASD refers to a broad set of behavioral disorders especially in social activities, communication, and repetition [3]. These disorders make the patients especially children have no social actions and friends because they have difficulties in communicating with others. They usually have habits to do something repeatedly alone. Some of them turn aggressive and violent when other people try to interact or communicate with them. Struggling to handle these problems among children might increase tensions in some parents. Parents have to spend hard time raising their children and have to dedicate a lot of time taking care of them. Unfortunately, there is no cure to ASD since its cause cannot be precisely and accurately determined. However, children with ASD can be improved using treatments designed specifically to each patient because each patient has different symptoms. Although the ASD conditions can be suppressed, expert therapists are hardly found, and children with ASD usually do not interact with people. These are two big issues in treating ASD patients. Surprisingly, these children can interact or communicate with objects, especially the objects having some movements. Therefore, the robot is considered as a tool in treating ASD patients. There are several researches using robots to treat autistic patients [4][5][6]. From recent researches, they suggest that the robots should be a shape of animals. Moreover, the robots should have some facial expressions and moving limbs [7][8]. But, the animal shapes might be unintentionally harmful to children with ASD because of its moving limbs since these children might aggressively interact with it and get hurt. In contrast, the facial expressions help improve communication skill and do no harm. Therefore, a circular-shaped robot with facial expressions are considered. The specific patterns of movement and sound are also integrated into the robot to investigate their effects in treatment.

## 2. Literature Review

There are several technologies used in ASD patient treatment. Among them, robotics are a promising technology because it can be served as a tool to effectively achieve specific therapeutic objectives as in Aurora project [9]. Nao is also a robot that used to investigate social engagement level of children with autism. A series of 4 single experiments were done using the Nao robot and the results were compared with the experimental results from those of social engagement with human partner to investigate whether the patients show more social engagement with the humanoid robot [10]. Technically, robots can be built into many shapes and appearances, and can have variety of functions. Several researches focusing on suitable shapes, appearances, and functions of the robot for treatment suggest that children with ASD do not interact with human-like or humaniod robots much. However, they feel comfortable to interact with non-human robots such as animals or objects [6][7][8][11]. Not only non-human robots can draw attention from these children but its functions or features such as moving limbs, facial and sound expressions are also required to draw more attention from them [8]. Additionally, there are more criteria to consider in building a robot such as safety, mobility, and autonomy [9][11]. Considering safety factor, an animal-shaped robot may hurt patients because there is a high chance that children with ASD will interact with the robot aggressively. The limbs and rough surface of the robot might scratch them. The robot should act like a safe toy and has a simple shape so that it is not too hard to get familiar with. Thus, [12] [13] proposed to use a spherical shape because it is a simple shape and has no sharp edges to hurt the patients. Moreover, a shperical robot can be easily adjusted to fit in variety of therapeutic objectives. The level of mobility and autonomy should also be considered, with high mobility for playing and interact easily.

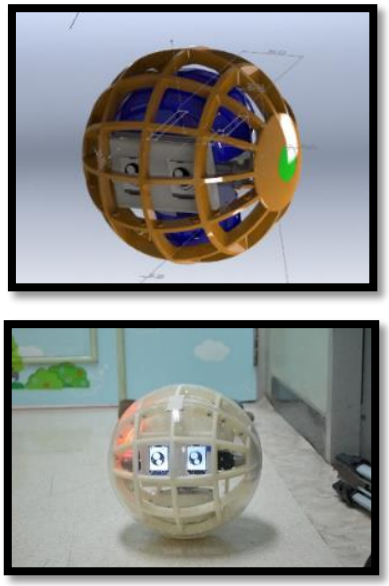

Figure 1. The "Puen Mai" robot in 3D program (above) and in action (below).

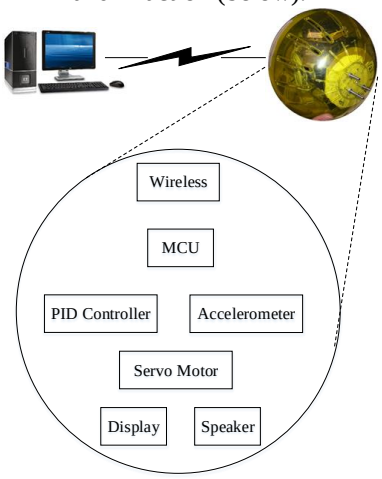


Figure 2. System diagram with main modules.

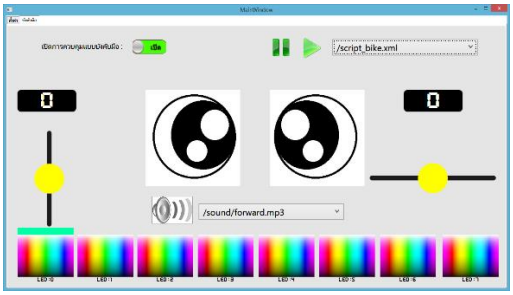


Figure 3. The user interface.

## 3. "Puen Mai" The Robot

The "Puen Mai" (a new pal) robot is designed to have a spherical shape with facial expressions, as shown in figure 1. At first, the design of the robot was done in 3D CAD software. The movements and expressions of the robot are designed and written into a script file, composed of a sound file and a XML script to allow the robot to talk and express predefined movements. A loop feedback controller is needed to manage accelerometer sensors inside. Values read from sensors are calculated to find the suitable speed to move servo motors to balance the robot's movements. The design will be described in the following subsections.

### 3.1 System Design

The purpose of this robot is to freely interact with the ASD patients, which are children, during their treaments. Therefore, the robot should be able to move easily and it should have simple shape that causes no harm to the children. The shape of shperical ball is hence used because it is a simple shape and has no rugged area or sharp edges.

In the treatment, the therapist will control the robot to response to the behavior of the patients accordingly. The robot therefore has to take command from the therapist wirelessly. There is user interface on a computer to communicate with and control the robot. Inside, there are a reciever and a microcontorller unit (MCU) to receive and process the command accordingly. The movement of the robot is functional by using a collaboration of PID controller, accelerometer sensor, and servo motor. Additionally, LCD display and speaker are used to display facial expression and sound. The diagram of the system is shown in figure 2.

### 3.2 Facial Expression, Sound, and Color Features

The facial expressions and sound are equipped to the robot in order to increase effectiveness of interaction between the robot and the patients. LCD screen is used as the eyes of the robot to express facial expressions. The user, therapist, can control the movement of the eyes. The color is also used to express the facial expressions. Moreover, there are three different sets of sound, namely human sound, animal sound, and robot sound, provided to express emotion.

### 3.3 User Interface

The user interface is designed to be user-friendly which can be used with the least training. The interface is simple. It has three parameters to be set as shown in figure 3. The pattern of color display can be selected from the predefined at the bottom of the interface. At the middle of the interface, there is a drop-down list for selecting the sound. Also, the eyes movement can separately be set for left and right eye using slide bars at the left and right of the interface. After these parameters are set, the user can transmit the settings to express accordingly by clicking "play" button.

## 4. Experimental Settings and Results

The experiment was set to suit autistic patients as requested by the Child Development Center, at the Ramathibordi hospital, Bangkok. To develop a robot for evaluating the social engagement level of autistic patients, the child development center provides knowledge consultancies about autism, experimental design, data collection, and a scenario for the experiments. For the first experiment, we expect the robot to fairly interact with the patients. Moreover, the robot should be able to endure the violence of the patients and should be safe to the patients. With the suggestions from the autistic treatment experts, we decide to do a two-stage experiment. In the first stage, data was collected to improve the robot by divide three groups of patients (with Low Functioning Autism (LFA), with High Functioning Autism

(HFA), and without Autism) to play with the robot, under close observation of the experts for 15 minutes each. From observed results, interactions between the robot and patients are varied. Compared to the children without Autism who enthusiastically interacted with the robot, the patients with LFA rarely interacted, while the patients with HFA had some interactions with the robot. From acquisitions, the treatment with a robot is promising for the patients with HFA.

After the preliminary acquisitions, the data collected from the experiment was analyzed. The second experiment was focused on the accomplishment of using many features of facial expressions. Three main functions of our robot are used as control variables to interact with the patients. They are movements (circular, forward, stop), sound (dog, human, robot), and colors (green, pink, yellow, blink). The experimental results have been observed and collected from the 3 minutes experiment each. The experiments were set with 4 HFA patients (aged 2 - 13 years old). The HFA patients are able to interact with other people. It was found that this group of patients responded very well to movement and sound of robot.

The final experiment was adapted from the results in the second experiment. The interaction of robot relied on the patient's movements. Unless the patient responded to the robot by looking at it or by moving toward the robot, the robot iteratively displayed its functions to stimulate the interaction especially with facial expressions. If the patient moved toward the robot, the robot would move away to encourage the patient to follow it. If the patient just looked at the robot, it would move toward the patient with sound to draw attention. The robot tried to draw attention from the patient to encourage the patient to touch and interact with it. After the patient touched the robot, the tester observed how the patient touched the robot. If the patient touched gently, the robot laughed or made other friendly sound. If the robot is touched violently, it would cry or make other sad sound. These steps make sure that the patient has an interaction with the robot. The actions of the robot as described will be repeated through 10-minute session of the experiment. In this experiment, patients aged 2-5 years old have more interactions with the robot than others. Some of the experimental results are shown in table 1. Detailed results are presented in following subsections.

Table 1. The summary of the experimental results

| **Function** | **Frequency of attentions** | |
|---|---|---|
| | **Eye contact** | **Interact** |
| **Movement** | 20 | 8 |
| **Sound** | 8 | 7 |
| **Color** | 9 | 3 |

### 4.1 Preliminary Acquisitions

At start, the experiments are done with a few patients to collect useful data to improve the robot. Interactions between the robot and patients are observed as followed.

The first patient is a LFA patient. The patient seemed not to have any interests in the robot and could not interact with other people except his parents. After 10 minutes, the patient started to show a little response to the robot. Parents and doctors had to encourage him to interact with the robot.

The second patient is a HFA patient. He had good response to the robot. He mimiced the movement and sound and also interacted with the robot by pushing. He paid attention to the robot more than 10 times especially the movement. In addition, he showed an interest how to control the robot.

The third patient is not an autistic. He thus paid high attention to the robot, especially on how to make it works. This patient interacted with the robot very well. he showed good responses to every function of the robot. He was also interested in the mechanism of the robot. He played with the robot by touching, lifting, hugging, and even imitating the movement and the sound.

### 4.2 Second Experiments

After the initial aqcuisitions, Puen Mai (the robot) was modified according to the data acquired. After modification, the second experiment was done focusing on the accomplishment of the robot by comparing the experimental results between our robot and the old robot currently used at the Child Development Center. In this experiment, movement, sound, and colors were used as control variables to interact with the patients. The movement consisted of a circular movement, a forward movement, and no movement. The sound consisted of dog sound, human sound, and robot sound. The colors consisted of blink, no blink and at random. The experiment with 4 HFA patients was done as followed.

The first patient was 12 years and 2 months old with symptom of ASD in language severe level. From observation, this patient paid attention especially to the eyes of the robot. he tried to find and looked into the robot's eyes. This attention lasted about 5 minutes. He seemed neither to scare nor afraid of the robot and its functions. He was interested in animal sound and the movement of the robot. His behavior was to only looking at the robot in some period of time. After that, he touched and paid more attention to the robot. Once, the robot displayed all abilities, he losted interest in the robot.

The second patient was 4 years and 11 months old with symptom of ASD in delayed speech. This patient was interested in the robot from the start. He touched the robot and touched its eyes as well. However, he paid attention to the robot for the short period of time, about 2 minutes and 30 seconds, when it displayed all functions. After that, he did not pay any attention to the robot at all.

The third patient was 2 years and 5 months old with symptom of ASD in delayed speech. The robot pulled attention of this patient at some degrees. He seemed to be happy to see the robot. He jumped happily, and watched the robot while it was displaying its functions. However, he seemed to be afraid of the robot so that he did not play with it. He was just looking and touching it sometimes. Also, he tried to ask his parents to see the robot. He paid attention to the robot for approximately 4 minutes.

The fourth patient was 2 years and 6 months old with ASD symptom. This patient liked spherical objects. Since our robot was also spherical object, he then kicked and throwed it. For this patient, the robot drew attention almost all the time of the test session. He played with the robot without fear and interacted with it sometimes. The attention to the robot was last about 7 minutes.

### 4.3 Final Experiments

From the second experiment, it was founded that the patients responded to movement and sound quite well. Therefore, the interaction of the robot based on movement and sound function are designed as followed.

The robot started with three main functions in order as followed: sound function, movement function, and color function. Unless the patient responded to the robot by looking at it or by moving toward it, the robot iteratively displayed its abilities in order. If the patient moved toward the robot, the robot moved away to encourage the patients to follow it. If the patient was just looking at the robot, it moved toward the patient with sound to draw attention from the patient. After that, the robot tried to draw attention from the patient to touch and interact with it. If the patient touched the robot gently, the robot laughed or made other friendly sound. If the robot was touched violently, it cried or made other sad sound. The actions of the robot was repeatedly through 10-minute session of the experiment.

The first patient was 4 years and 1 month old with ASD symptom. From observation, this patient has agoraphobia and anxiety in situations where the patient could sense that the environment was dangerous. He then resisted and started to yell for his parents. Therefore, the treatment could not be done properly and the data could not be collected.

The second patient was 4 years and 7 months old with ASD symptom. The patient showed his attention in spherical objects clearly. He kicked the robot immediately when he saw it. Therefore, the patient had to be calmed down so that the experiment could continue. He still treated the robot as a ball. But this time, he touched it and paid attention to the color functions of the robot. He had no interest in the sound functions of the robot at all.

The third patient was 12 years and 5 months old with ASD symptom. This patient was quite old. He had little interest and interaction with the robot. He showed little interest in the robot by looking at the robot when it tried to draw attention from the patient. Besides, he paid attention when the robot used sound and color function.

The fourth patient was 10 years and 4 months old with ASD symptom. This patient saw the robot as a ball. Thus, he kicked it most of the time. Sometimes, he touched it with his hands. He did not show any interest in sound and color function of robot.

## 5. Conclusion

The effects of facial expressions, sound pattern, color pattern, and movement pattern of the spherical robot to the treatment of children with ASD have been investigated in this paper. The robot has been built into a spherical shape because it is safe. Therefore, the robot is easy to play with and has no sharp angles or rugged surface to hurt children. The robot has been designed to be semi-autonomous so that it can provide proper responses in accordance with children interactions. The experimental results show that 75% of patients pay more attention to the robot. Forward movement can draw attention from patients the most. The second and third are animal sound and color expressions.

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