JAREE-Journal on Advanced Research in Electrical Engineering
Volume 3, Number 1, April 2019

Implementation of Ichiro Teen-Size Humanoid Robots For Supporting Children Autism Therapy

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***Abstract*—The humanoid robot is a robot which has human-like shapes and/or functions. For instance, a humanoid robot has a neck that connect the head to the body, two legs to support the body, and has two arms on the right- and left-side of its body. According to the *RoboCup* competition, the humanoid robot can be classified into several types based on their sizes, i.e., kid-size, teen-size, and adult-size. In this study, we developed a teen-size humanoid robot with the aim of approaching the size of children's bodies with autism to facilitate the interactions between the robot and the children. In general, the autism person is difficult to communicate with a normal person because there is a virtual wall that limits the world of the autism with the normal person. As long as the wall is standing upright, communication will be difficult, so that inconvenience occurred on both sides. Especially in children, the process learning will be hampered if communication is blocked. In many cases, the autism children more actively interact and/or communicate with objects such as books, toys, and so forth. This motivated us to use a humanoid robot as a mediator of interactions and/or communication with the autism to support their therapy. Of course the choice of humanoid robots must also be considered both financially and functionally. At present there are many commercial humanoid robots such as: NAO, Darwin-OP, and so forth. However, the price offered is relatively expensive and also inflexible capabilities because existing hardware and software can no longer be freely developed. Flexibility in hardware and software is very important for the implementation of a system that can be used in supporting the therapy for autism. These facts motivated us to develop the Ichiro teen-size robot. In this study, we developed a therapy for autism in the form of interactions involving the movements of the robot such as a gymnastic movement, playing soccer, and so forth. The movement is expected to be able to be followed by the autism and has a positive impact on therapy. One of the advantages of this study is being able to add robot movement flexibly, so that the movements suggested by psychiatrists should be able to be implemented and help to support the autism.**

Keywords—Humanoid robots, therapy for children autisms, robot's movements, RoboCup.

I. Introduction

Indonesia has entered an industrial era 4.0 where the development of technology, information and communication has become a significant factor. This also has an impact on the field of robotics, including the humanoid robots. A humanoid robot is a robot that has a human-like shape like having two legs that support the body, on the left- and right- side there are two arms, and also a neck to connect a head. According to *RoboCup* rules [1], the humanoid robot can be classified into several types based on its size, i.e., kid-size, teen-size, and adult-size. In this study, we developed a teen-size humanoid robot with a height of about 85 cm. The size of this teen-size was chosen with the aim of approaching the body size of the children, especially for ones with autism to facilitate the interaction between the robot and them.

Fig. 1. Ichiro the humanoid robot teen-size.

In general, the autism is difficult to communicate with normal persons because there is a virtual wall that limits the world of sufferers with the normal persons. As long as the wall is standing upright, communication will be difficult, so that discomfort occurs on both sides. In particular, the cognitive learning and growth process of the autism children will become hampered if communication is blocked. In many cases, autism children are more actively interacting and/or communicating with objects such as books, toys, and so on. This motivated us to use humanoid robots as mediators for interaction and/or communication with the autism to support their therapy.

The first problem faced in this study was the choice of humanoid robots as a medium for interaction between children and robots. Of course the choice of the robot must also be considered both financially and functionally. At present there are many humanoid robots available in the market such as: NAO [2], Darwin-OP [3], and also IGUS [4]. However, the price offered is relatively expensive and also the ability is not flexible because the existing hardware and software can no longer be freely developed. Flexibility in hardware and software is very important for the implementation of a system that can be utilized in therapy for children with autism. This reason made us choose the implementation of the teen-size

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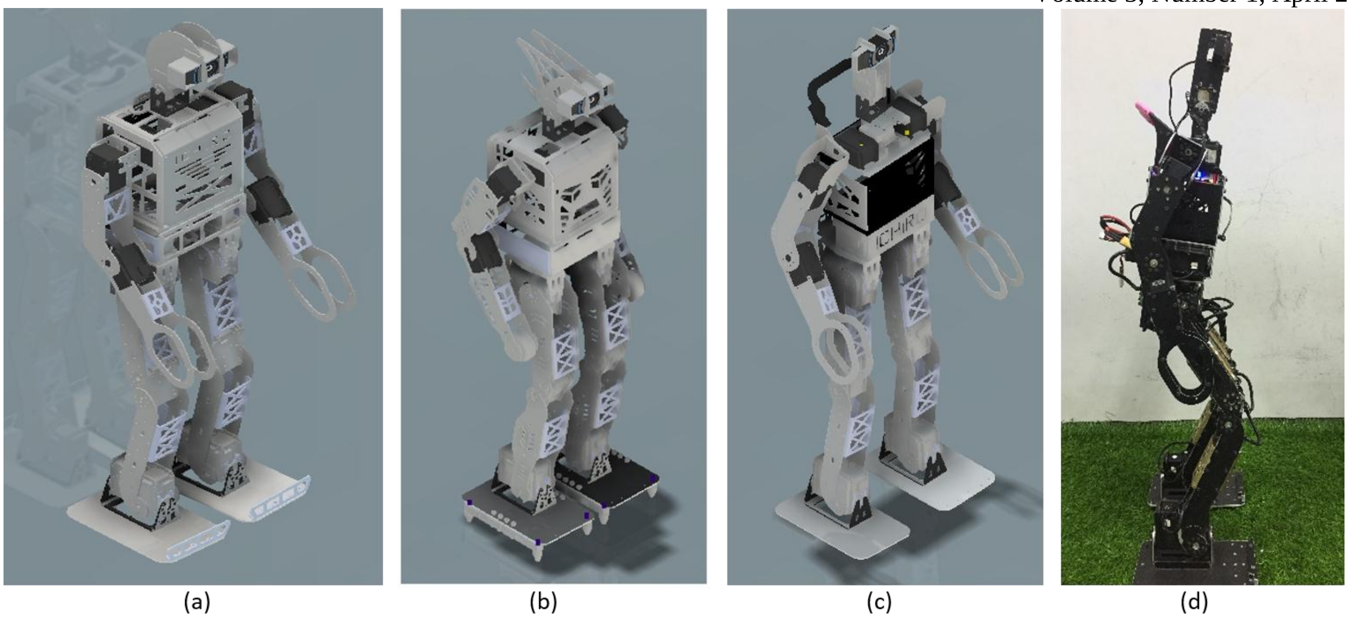

Fig. 2. Design of Ichiro Teen-Size: (a) the CAD design of Ichiro teen-size Type-1, (b) the CAD design of Ichiro teen-size Type-2, (c) the CAD design of Ichiro teen-size Type-3, and (d) the Ichiro teen-size Type-3 in real picture.

Ichiro shown Fig 1.

The second problem is how to attract the attention of these autism children. We can explore this through experiments with several types of robot parts such as the head, arms, and body of the robot. Especially for the robot's head we can modify and compare several types, to get good results.

In this study, we developed a therapy for autism in the form of interactions that involve the robot's movements such as ones in the gymnastic, playing soccer, and so on. The movement is expected to be able to be followed by people with autism and have a positive impact on therapy.

This research includes two fields of studies. First related to the implementation of humanoid robots, especially teen-sized ones. Study about development of humanoid robots has been discussed. For example, for commercial use there are NAO [2], Darwin-OP [3], and for non-commercial use there are IGUS [4], ARMAR [5], a domestic service robot in [6], and so forth. The robots are quite good and worth trying in this study. However, the price is relatively expensive and the unavailability of sufficient information made us decide to develop Ichiro.

Second, this study also deals with the field of interaction between robots and humans in general and interactions between robots and children in particular [7], [8], [9]. In [9], they tried to measure the attention of a child with a commercial robot Pepper [10] by using the help of sensors installed in the classroom. Such a study inspired us, whereas in this study, we emphasize the attention to the autism through the interaction with a humanoid robot.

II. Overview of Ichiro teen-size

In this section, we introduce Ichiro teen-size humanoid robot; the robot used in this study. At the first time, Ichiro was developed for humanoid soccer competion in the *RoboCup* [1]. Our robot then evolved and became a multi-purpose robot including supporting the therapy of autism. To know further about the Ichiro, we will elaborate the development of our robot.

A. Mechanical hardware overview

Ichiro teen-size Type-1 (see Fig. 2 (a)) is the first robot teen-size that we made based on a modification from Nimbro-OP [11]. We still use these robots because of their robustness and stability. Thanks to our stability control design so that the robot able to perform a long shot.

This robot uses one Logitech camera C922 and two LiPo 4S batteries with 300 grams weight. There are 20 degrees of freedom that are realized by using the combination of Dynamixel servos. Twelve Dynamixel MX 106 for the robots feet, six Dynamixel MX 64 for the robots arms and two Dynamixel MX 28 for the head (see Fig. 3). Ichiro teen-size Type-1 has 85 cm of height. This robot is made by cutting and bending with 3 mm thick type 5 Aluminum material. To support the balance of the robot, we used four load cells with a capacity of 10 kg for each leg. We made the loadcell system based on the Rhoban Football Club Team's foot sensor system [12].

Ichiro teen-size Type-2 (see Fig. 2 (b)) is the second version of Ichiro teen-size robot. This robot is a development of Ichiro teen-size Type-1. There are three main points of the development of this robot, there are aesthetics, workmanship,

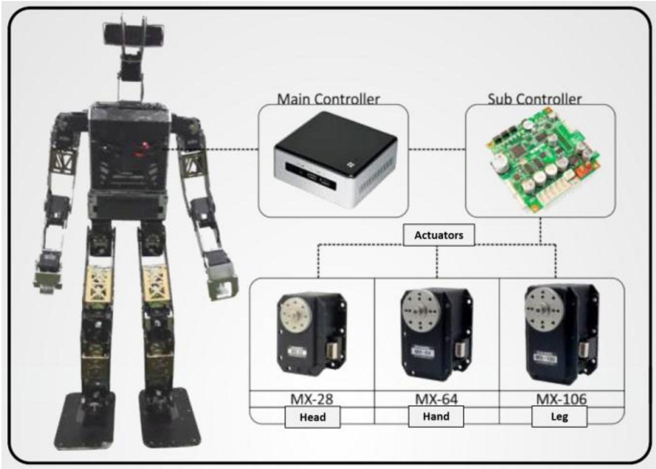

Fig. 3. Ichiro teen-size Type-3 and its specifications.

and performance functions. The design is made better by giving holes on the aluminum sheet. Changes to the legs are made for an easy assembly of Dynamixel servo. We enhanced the robot arms, we added a pair of wheels with nylon material to facilitate waking up performance. Thus, the robot has a height of 86 cm.

Ichiro teen-size Type-3 (see Fig. 2 (c), and (d)) is the enhancement of both Ichiro teen-size Type-2 and Ichiro teen-size Type-1. Innovations were made because of the existence of robots that have low running speeds. This robot has a height of 84 cm and weighs 7.2 kg. This robot has an improvement in the body and upper arm. Enhancement is done by reducing the weight. This improvement will affect the position of the center of gravity (CoG). By lowering the CoG, robots are expected to run faster. The arm is changed to protect the servo when the robot falls. Ichiro teen-size Type-3 uses aluminum type 5 with 3 mm thickness for legs and type 6 aluminum with 2 mm thickness for other body parts.

B. Electrical hardware overview

Ichiro teen-size uses an Intel NUC mini PC as its main controller as shown in Fig. 3. For the visual sensor, we are using a Logitech C922 camera that plugged on the USB port on Intel NUC.

For the orientation sensor, we have used MPU-6050 where this sensor is quite accurate with a 16-bit analog to digital converse internal hardware facilities for each channel. This sensor combines the 3-axis gyroscope and 3-axis accelerometer on the same chip. A microcontroller such as Arduino is needed as an interface for I2C-bus, in order to interact with MPU-6050. In our robot, we used Arduino nano as an access to this sensor.

For joints movements in our robots, it is driven by a servo motor. There are 20 joints on the robot and we use a combination of Dynamixel MX-28 servo, Dynamixel MX-64 servo, and Dynamixel MX-106 servo. There are six Dynamixel MX-106 servo motors on each leg. In the hand, three Dynamixel

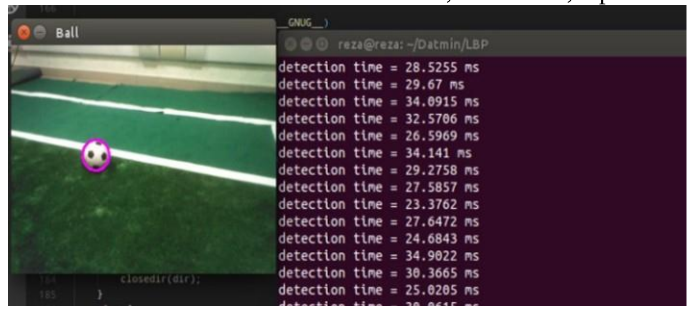

Fig. 4. An example of LBP-based ball detection.

MX-64 servo motors are used in each hand and on the pan and tilt, there is two Dynamixel MX-28 servo motor. To interact with a servo motor, we have used a sub-controller in the form of a cm-740.

This robot requires supply power with a voltage range of around 12 volts to 19 volts. We use a 4-cell LiPo battery, 3300 mAh. Supply power is intended for Intel NUC and cm-740, but for cm-740 we only use a supply power of 16 volts.

For the current version of our robot, the control system that we used is the same with one developed in [13]. We did not make any changes in electrical terms. We only minimized the board by combining the power switch board and MPU-6050 board into one to make it more compact and minimalist.

III. INTERACTIONS FOR SUPPORTING THERAPY OF AUTISM AND THE QUALITATIVE EXPERIMENTS

As mentioned above, there are several types of Ichiro teen-size robot. In this study we used the robot shown in Fig. 1. To support the therapy of children with autism, some interaction modules were developed. The first module was a module that can generate the gymnastics or light exercises. Ichiro was also able to do human-like activities such as walking, lifting things. Fig. 6 shown the abilities of Ichiro in generating the movements to support the autism. From the figure, one can see that qualitatively Ichiro was able to perform the gymnastic movements. These movements can be used in supporting the therapy of autism children. This result showed that the implementation of the movements to support the autism children had been successfully done.

The second module implemented for the interaction was the vision module to play the soccer game. We developed the vision module according to the rule in the RoboCup to get a better game representation. To compete for a humanoid soccer league, a vision system is needed to detect the ball, a soccer field, and so forth. Our previous method used ball detection by filtering it according to color, shape, and size. However, due to the significant changes in the *RoboCup* regulation, specifically using the dominant white ball, white goal post, and synthetic grass, the previous method was no longer efficient to be used.

To realize a better vision system, we implemented a detection method that robust to the light changes, high accuracy, low computation and less parameters to be tuned. For ball detection, we use a Local Binary Pattern (LBP), which is a texture

TABLE I. NETWORK LAYER OF MOBILENET V1 [17].

Type / Stride	Filter Shape	Input Size
Conv / s2	3 x 3 x 3 x 32	224 x 224 x 3
Conv dw / s1	3 x 3 x 32 dw	112 x 112 x 32
Conv / s1	1 x 1 x 32 x 64	112 x 112 x 32
Conv dw / s2	3 x 3 x 64 dw	112 x 112 x 64
Conv / s1	1 x 1 x 64 x 128	56 x 56 x 64
Conv dw / s1	3 x 3 x 128 dw	56 x 56 x 128
Conv / s1	1 x 1 x 128 x 128	56 x 56 x 128
Conv dw / s2	3 x 3 x 128 dw	56 x 56 x 128
Conv / s1	1 x 1 x 128 x 256	28 x 28 x 128
Conv dw / s1	3 x 3 x 256 dw	28 x 28 x 256
Conv / s1	1 x 1 x 256 x 256	28 x 28 x 256
Conv dw / s2	3 x 3 x 256 dw	28 x 28 x 256
Conv / s1	1 x 1 x 256 x 512	14 x 14 x 256
5 x Conv dw / s1	3 x 3 x 512 dw	14 x 14 x 512
5 x Conv / s1	1 x 1 x 512 x 512	14 x 14 x 512
Conv dw / s2	3 x 3 x 512 dw	14 x 14 x 512
Conv / s1	1 x 1 x 512 x 1024	7 x 7 x 512
Conv dw / s2	3 x 3 x 1024 dw	7 x 7 x 1024
Conv / s1	1 x 1 x 1024 x 1024	7 x 7 x 1024
Avg Pool / s1	Pool 7 x 7	7 x 7 x 1024
FC / s1	1024 x 1000	1 x 1 x 1024
Softmax / s1	Classifier	1 x 1 x 1000

descriptor popularized by Ojala et al. [14]. Unlike the Haralick texture feature that calculates global texture representations based on the Gray Level Co-occurrence Matrix, LBP calculates local texture representations. This local representation is built by comparing each pixel with the surrounding pixels. The result of ball detection is shown in Fig. 4.

For the classification process, we use the cascade classifier [15], [16]. Cascading classifiers are trained with hundreds of ”positive” and ”negative” images of the same size. This method is very suitable to run on a low-power CPU because it has a fast processing speed. To reduce noise outside the field, we first segmented the color of the field based on the color. From the contour detected, the contour that had the largest area was selected and then Convex Hull was performed. After that, we classify it using the LBP feature on the object inside convex. With this method, satisfying results have been achieved. The robot could detect balls in a maximum distance of 400 cm with a detection time up to 19 ms.

We also tried another method to detect many objects in the soccer field. We used the architecture of Mobilenet v1 [17] and used a Single Shot multi-box Detector (SSD) for object localization. Table I shows the implementation of Mobilenet v1 whereas Fig. 5 shows the implementation result in Ichiro robot. These results were for the qualitative evaluation for the implementation of the interaction modules for supporting the children with autism.

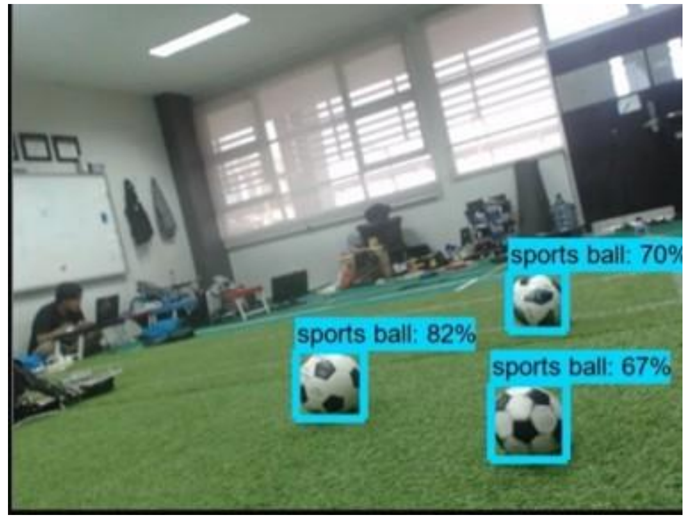

Fig. 5. An example of ball detection using deep learning.

IV. CONCLUSION

In this study we have developed a teen-size humanoid robot Ichiro. To support the therapy of children with austism, we developed two interaction modules. The first module was the module to generate and control the movements of our robot. We have implemented several movements which similar to the gymnastic movements. The results have shown that Ichiro has been able to performed the gymnastic movements resemble to humans. The movement can be used to help supporting the children with autism. We have also developed the second module for playing soccer. Vision module was also implemented to Ichiro to support soccer game. Several qualitative evaluations have been made, and the results have shown a good potential for Ichiro to support the children with autism.

A quantitative evalution such as taking questionnaire on the interactions such as our robots movements is one of our future work. We also plan to test the attraction made by those movements to the children with autism.

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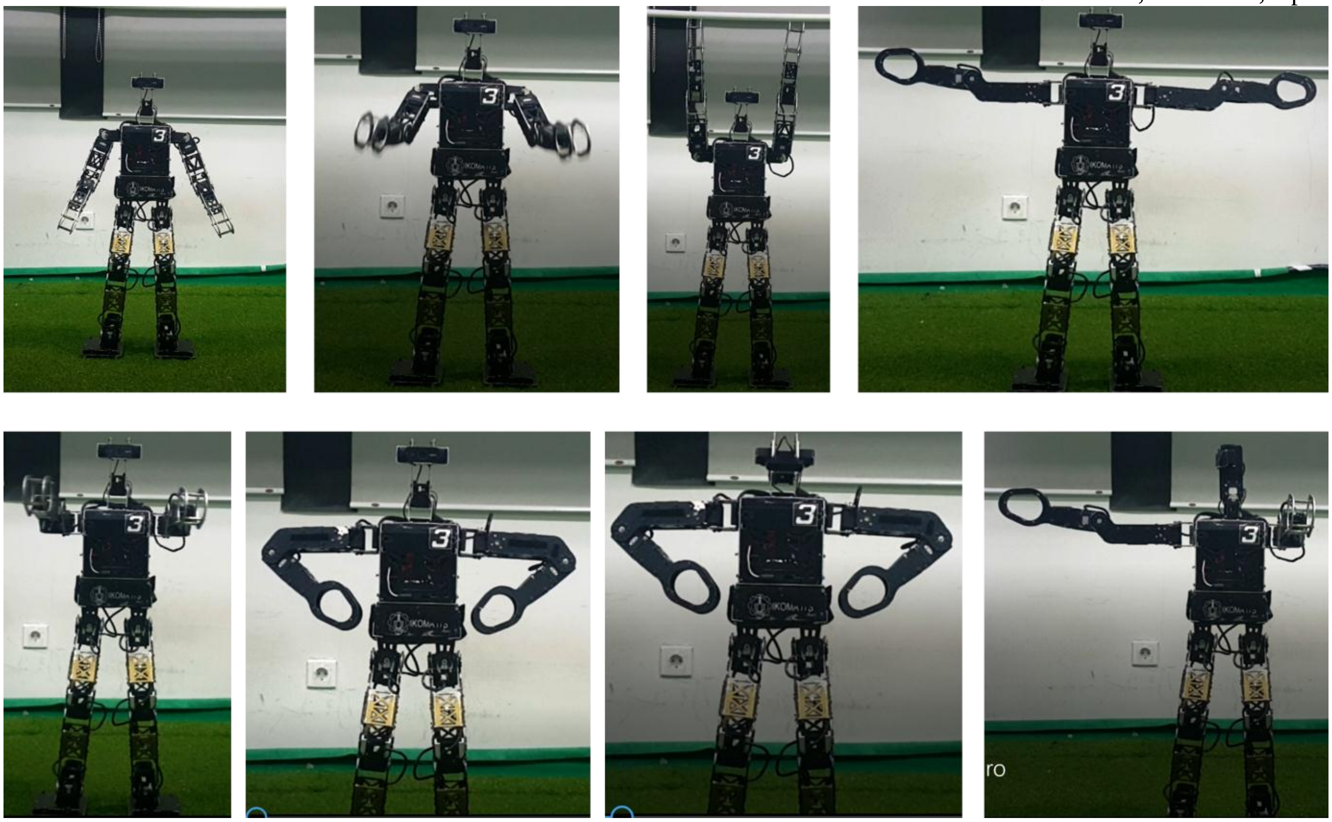

Fig. 6. Examples of Ichiro robot's movements.

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