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# Low-Cost Mini Humanoid Robot Mechanical Design for Mini Humanoid Robot Contest Intercon 2021

Ronny Vilavila, Frahan Justo, Ruben Florez and Nícolas Figueroa

***Abstract*—This paper describes the mechanical design of a low-cost mini humanoid robot for the Mini Humanoid Robot Contest Intercon 2021. The objective is to provide a robot model with the appropriate characteristics to program control and locomotion applications within reach of anyone. BERT is made up of 16servomotors (DOF), distributed 10 in the legs and 6 in the arms controlled by a PCA9685 driver; the body is assembled with 3 mm thick MDF pieces, and the device that controls the robot's march is an Arduino pro mini. The mechanical design of the leg, arm, and torso provides balance to the robot and possesses enough strength to perform movements without the risk of breaking. The results show that the presented design is stable and consistent for programming control and locomotion applications.**

***Index Terms*—Mechanical design, mini humanoid robot, low-cost, medium-density fiberboard MDF, bipedal robot.**

## I. Introduction

Currently, there is a significant limitation in terms of access to develop humanoid robots because they are expensive [1], complex, and time-consuming to develop. However, mini-humanoid robots are an alternative to understand and study the structure of a small-scale robot. The KHR-3HV robot, for example, is a mini humanoid whose structure is designed with polycarbonate and ABS [2], which makes it lightweight. In addition, 17 servos (DOF)KRS-2552RHV [3], [4] and the proportions of its design allow it to generate motion controls very similar to humans [5].

On the other hand, there are mini-humanoid robots that are designed for competitions. These allow designers to learn about the structure of a robot in the construction process.INTERCON 2021 is a congress in Peru where a new category in low-cost mini humanoid robotics is opening [6]; to allow students and people who are fond of robotics to create designs and get closer to knowledge about mini humanoid robots. This paper aims to provide a mechanical design of a mini humanoid robot, with components within reach of anyone.

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## II. Canon of the 8 heads

The design of BERT, a mini-humanoid robot, is based on the 8-head canon Fig. 1, which is considered as the ideal model of the human body [7]. For this reason, the ratio of the 8 heads provides stability in the mechanical design when generating movements in the mini humanoid robot.

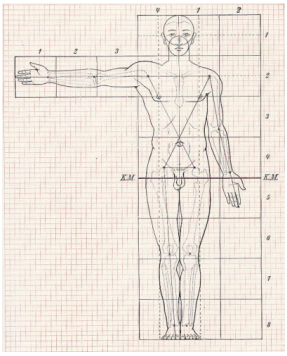


Fig. 1: Canon of the 8 heads.

## III. State of art

A low-cost mini humanoid robot can be created using easily accessible components such as Arduino, micro servos, servo control driver with a simple and robust mechanical design, easy to operate through simple programming [8], [9].

On the other hand, although it has limitations to use low-cost components, a significant advantage is that it would have the availability of programming control and locomotion applications [10].

Currently, an example of a low-cost humanoid robot is CALUMA. It is easy to operate and low cost. Its design and control give him the ability to walk straight, pick up an object, and walk with it in his hands [11].

In addition, the model in which BERT's design and construction were inspired is the KHR-3HV mini humanoid robot, due to the excellent design and distribution of its servos, which allows it to have stability and to produce motion controls like humans [12].

## IV. BERT's Overview

The design of this low-cost mini humanoid robot consists of 5 SG90 micro servos on each leg and 3 SG90 on each arm, as shown in Fig. 8a. It has a height of 28 cm, a width of 14 cm, as seen in Fig. 2, and 312 grams. The robot is equipped with an Arduino pro-mini with an ATmega 328p microcontroller; likewise, it consists of a controller (PCA9685) for the servomotor Fig 8a16. The body of the BERT mini humanoid is composed of pieces of medium-density fiberboard known as MDF, 3 mm thick, cut by laser, see Fig. 3b. In addition, according to the competition [6]; this proposed design aims to generate simplification in terms of its programming

## V. Cost Oriented Design

The aim of the design of the mini-humanoid robot called BERT is that it will be used by students and enthusiasts in the field of robotics, under the design concept of the low-cost mini-humanoid robot, of lightweight, low cost, easy to assemble, and with an aesthetic appeal.

Therefore, to meet these requirements, the robot has the following characteristics: Table 1.

TABLE I: Features of mini humanoid robot (BERT)

| | | |
|---|---|---|
| General | Weight | 312 [g] |
| | Height | 28 [cm] |
| | Width | 14 [cm] |
| | Depth | 4 [cm] |
| | Material | MDF of 3 [mm] |
| | Battery 4x18650 | Lithium (7.2V,2000mAh) |
| | Time of operation | 1 hrs |
| | Servo speed | 100ms per angle |
| | Degrees of freedom | 16 DOF |
| Actuator | Micro servo SG90 1.8 kgf·cm | 16 micro servos |
| Electronic | Arduino Pro Mini 5v 16 Mhz | 1 unid |
| | PCA9685 6V 12 bits | 1 unid |
| | PStep-Down MP1584EN 3A | 1 unid |

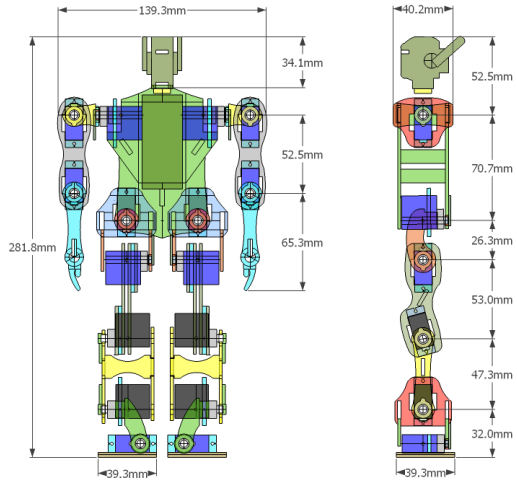
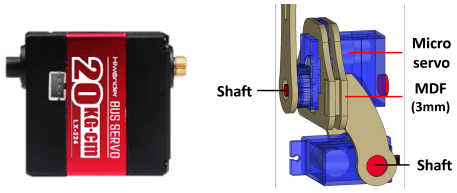



Fig. 2: Dimensions and joint axis BERT mini Humanoid robot.

### A. Articulation between servos

The joints are designed so that the servo does not suffer an over-tension on the gear shaft. For these joints, it is recommended to use double-axis servos [13], [14], as can be seen in Fig. 3a. The SG90 micro servo [15], has a drawback because it has only one axis. An additional axis is added on the opposite side to the servo axis, as shown in Fig. 3b.

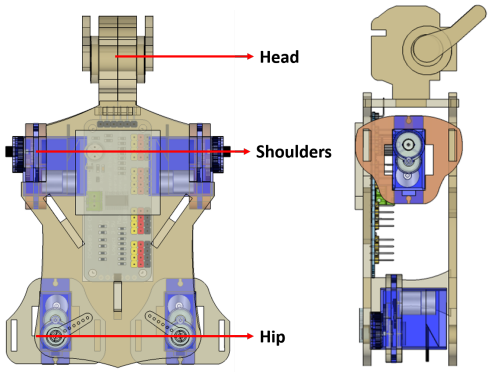



(a) [13] (b)

Fig. 3: Mini humanoid-BERT joint design.

### B. Torso

The mechanical design of the torso houses the hip and shoulder servos and the location of the PCA9685controller. This design helps the legs have a rotation angle of 100 ° in the sagittal plane, in the shoulders a 180 ° angle of rotation in the frontal plane, as shown in Fig. 4.




(a) (b)

Fig. 4: Mini humanoid-BERT Torso Design.

### C. Legs

The mechanical design of the legs is essential in bipedal robots because they allow imitating the movement of human walking [16]. There are five micro servos on each leg, made up of 2 micro servos on the hip, one micro servo on the knee, and2 micro servos on the ankle. The micro servo No. 8 and No. 9Fig. 8a respectively of each leg is inside the torso at the bottom(hip), as seen in Fig. 4a. The design of the 3D leg mechanisms shown in Fig. 5a, 5b. The chosen MDF material can bear the weight of the body, the torque of the micro servos, so there will be no problem with the structure's sturdiness.

*1) Sagittal and frontal plane ankle:* The degree of freedom of the ankles is designed for a rotation of 107 degrees in the Sagittal plane and 180 degrees in the frontal plane.

*2) Knee frontal plane:* The Knee has a 180 ° degree of freedom in the frontal plane.

*3) Hip plane frontal and sagittal:* The hip has a degree of freedom of 180 ° in the frontal plane and 100 ° in the sagittal plane. The micro servo of the sagittal plane is inside the torso supported by the joint.

### D. Arms

The mechanical design of the arms is essential for the robot's stability when walking, handling objects, getting up after falling, and other movements. It consists of 3 micro servos on each arm, one micro servo on the elbow, and two micro servos on the shoulder, as shown in Fig. 5c, 5d. The micro servo No. 13 and No. 14 Fig. 8a of the Frontal plane is inside the torso held by the MDF see Fig. 3b.

*1) Elbow sagittal plane:* The elbow has a 180 ° degree of freedom in the sagittal plane.

*2) Shoulder plane frontal and sagittal:* The shoulder has a degree of freedom of 180 ° in the frontal plane and 180 ° in the sagittal plane.

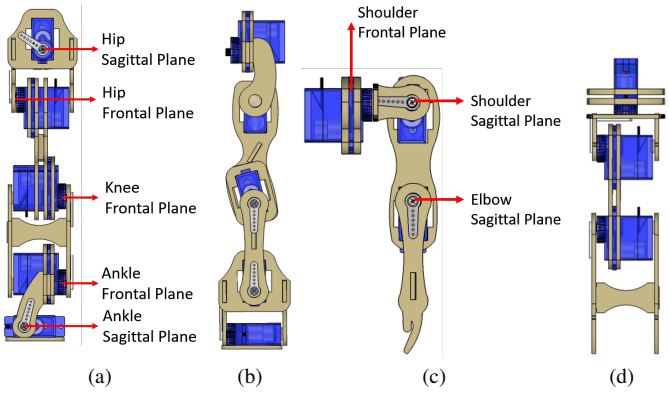



Fig. 5: BERT Mini Humanoid Robot Arm 3D Design.

## VI. Mechanical Construction

The whole body structure is designed to be easy to assemble; it consists of 54 laser-cut piecesFig. 6, Fig. 8. MDF was chosen as the material for the mechanical construction, this material was chosen for its hardness, lightweight, low cost, and easy handling [17], unlike3D printing, this printing is the high cost [18] because of its material (filament) and the time to be performed [19]. Other materials are balsa wood and popsicle sticks. These materials are fragile to the sudden movements produced by the robot. They tend to break.

The protruding part of the piece fits into the groove of another piece, as shown in Fig. 7. This type of assembly keeps the pieces together very well, but for better adhesion, instant glue is used between the joints, this because the robot movements exert tension on these. It is suggested first to assemble the fixed parts as shown in Fig. 7. The next step

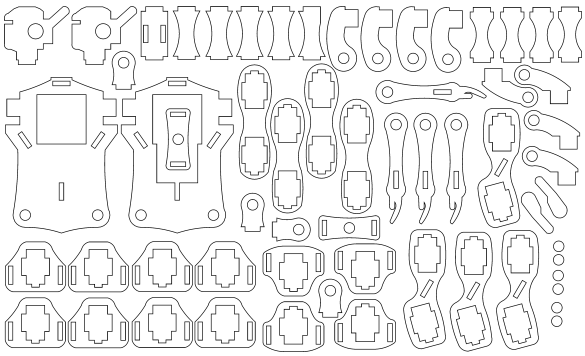


Fig. 6: Design of the pieces to be cut of the Mini humanoid-BERT robot.

is to calibrate the micro-servos at 90° degrees for the vertical position of the robot, the legs should be upright, and the arms should be straight and close to the torso. This is to facilitate the programming of the robot's movements. Once the calibration is ready, we proceed to join the pieces with the joints.

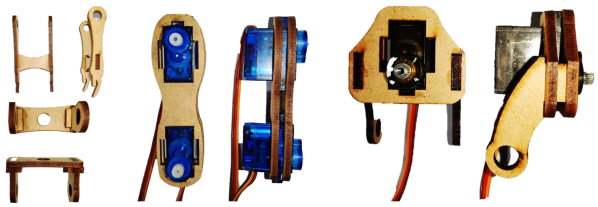


Fig. 7: Assembling the fixed parts.

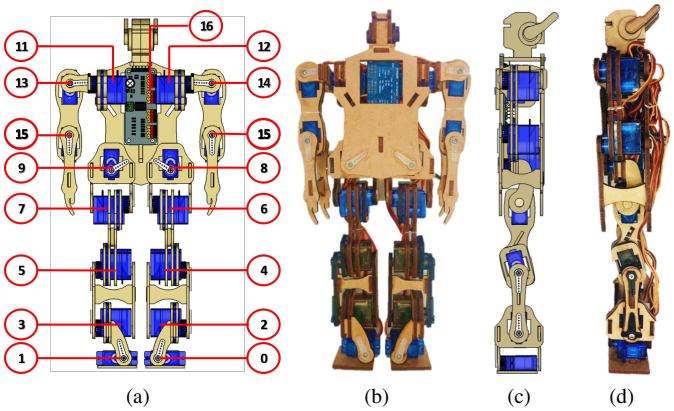
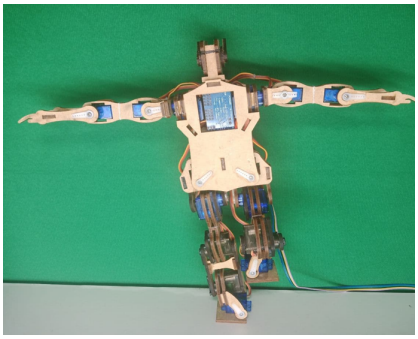



Fig. 8: Corporation for 3D simulation and physical assembly of the Mini Humanoid Robot-BERT.

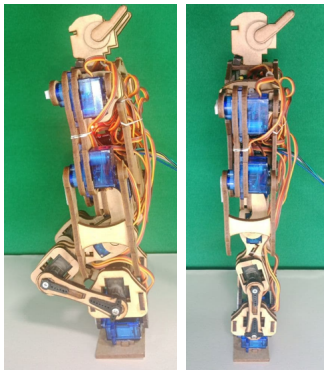
## VII. Results and Evaluations

We proposed a mechanical design of a low-cost mini-humanoid robot using laser-cut MDF for the robot body and using 16 optimally articulated servos for the correct functioning of the legs and arms. In this article, the dimensions, materials, and design of the robot and its mechanical construction, shown in detail in different parts (joints, torso,

arm, and leg), were presented. When laser cutting the parts, we noticed an error of 0.1mm, making the parts fit soles slightly and help not force the joints then fixed with glue which makes them much more resistant to fall off the robot accidentally. A very convenient feature of the design is that no bolts or nuts are used for assembly, making it lightweight, as shown in the robot weight table. 1. It should be noted that the SG90 micro servos have a torque of 1.8 kgf-cm, which is sufficient for the model that was designed to be light. It can be mentioned that the weight distribution of the robot was in the proportion of canon of 8 heads. This makes the robot maintain balance in a vertical position or on one leg where it is observed in Fig. 9a, 9c. During the motion tests, it could be seen that the leg servos have enough strength to lift the body with the knees bent, as shown in Fig.9b and the arms, as shown in Fig. 9a. The time is taken for the robot to move from the kneeling position Fig. 9b to the upright position Fig. 9b is 7 seconds with a servo speed of 100ms per angle. The 3D design did in the software SketchUp's pro-2016 of 30-day trial version helped a lot in the assembly of the robot and the movements' configuration. We can conclude that the robot is fully functional and versatile, and easy to use.



(a)



(b) (c)

Fig. 9: Result of the movements of the Mini Humanoid Robot-BERT.

## VIII. Conclusions

This article presented the mechanical design of BERT, a low-cost mini humanoid robot assembled with low-budget materials with an approximate cost of 100 dollars. The MDF provided the robot with a stable and aesthetic design due to its hardness and easy handling. Likewise, we can conclude that the robot has the necessary characteristics of applicability, functionality, and versatility to be used by students and people fond of robotics, as shown in the results obtained. In addition, we propose a future implementation using artificial vision to control the robot's movement through image recognition. [20].

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