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Eleven Degree of Freedom Humanoid Upper Body Robot SIBO

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***Abstract*—Rapid technological advancement is an asset that can be leveraged to preserve culture. This article carried out the assimilation of robotic technology into a culture. This study's first design was accomplished by simulating a humanoid robot using a three-dimensional model. This study focuses on the experiment of the SIBO welcome robot, which replicates the humanoid upper body's movement with eleven degrees of freedom. This research investigates the SIBO welcoming robot by imitating the movement of the upper body humanoid with eleven degrees of freedom. Blender application is used to create 3D models and rigging for size simulation and estimation of robot movement. The implementation of the actual robot uses low-cost materials and a second-hand motor power window car as the actuator. This robot casing uses concepts and materials with the nuances of Balinese culture, namely 'Ogoh-Ogoh'. The combination of art and technology creates the SIBO welcoming robot.**

Keywords—eleven dof, humanoid robot, mechanical design, robotics, simulink

I. Introduction

Rapid technological advancement poses no threat to cultural sustainability. This advantage can be used to assimilate technology and culture. This work created a robot with a traditional Balinese (Ogoh-ogoh) casing to welcome guests. The initial stage of this research is modelling.

Modelling is currently one of the most crucial steps in the design of mechatronic devices and robotic systems [1]. Various modelling and simulation software is used to speed up the development process and identify and eliminate errors early [2], [3]. Several 3D CAD robot modelling studies have been carried out using Solidworks software [4]–[6]. An additional fee is required to use the service of this software.

The main focus of this research is designing and manufacturing the SIBO upper body humanoid robot, which is intended as a welcoming robot. The 3D model was created in this study using the open-source software Blender. Several studies on the simulation and design of robots using Blender have also been carried out [7]–[9]. Blender has several features that support measuring and simulating the robot's movement. Using Blender software is very significant in reducing the cost of purchasing software.

The initial process of 3D model design is carried out in Blender with the planned size. After the 3D model has been generated, the next step is assigning a bone to each 3D object so that its movement can be controlled and simulated. After obtaining each joint's size, placement, and minimum/maximum rotation angle, the next step is the development stage.

Several second-hand power window motors are used as joint actuators. As a bone or connection between joints, this robot's design incorporates a cylinder of iron and a cube with a hollow interior. The outcomes of this investigation are provided in the form of a SIBO robot in the subsequent chapters.

II. SIBO: Overall Description

STIKOM Bali Robot (SIBO) is an upper-body humanoid robot created to welcome guests. The name SIBO comes from a university where this research was conducted, ITB STIKOM Bali [[10]. The height of this robot is 160 cm, with a weight of 50 kg. This robot was built using a used car power window motor as an actuator in each joint (Fig. 1). Robot design is made by considering robot stability, wiring path, connection position, and casing. The manufacture of this robot also pays attention to the appearance of the robot with a traditional Balinese-Indonesian art design concept.

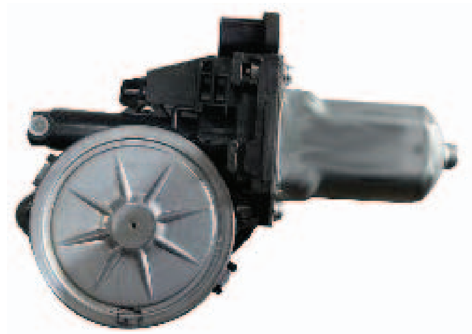


Fig. 1. Second Hand Power Window as Actuator.

III. Research Methodology

A. Human Upper Body Motion

The interrelated bones, joints, muscles, and tendons that affect the human body's mobility are tough to replicate and apply to a robot. Consequently, the mechanical design emphasizes mimicking human movements. Humanoid robots' mechatronic design is essentially the capacity to interact with humans. Kinematic characteristics and motion range must be tuned to human and environmental conditions [11]. People must accept robots since they interact with humans to fulfil diverse functions. Human-like appearance is equally as crucial as a human-like movement [12].

B. SIBO Degree of Freedom Configuration

SIBO has 11 degrees of freedom focusing on the upper body. The upper body consists of the Shoulder, Elbow, Wrist, Neck, and Torso modules. The kinematics of this module is shown in Fig.2.

*ITB STIKOM Bali fully funds this research.

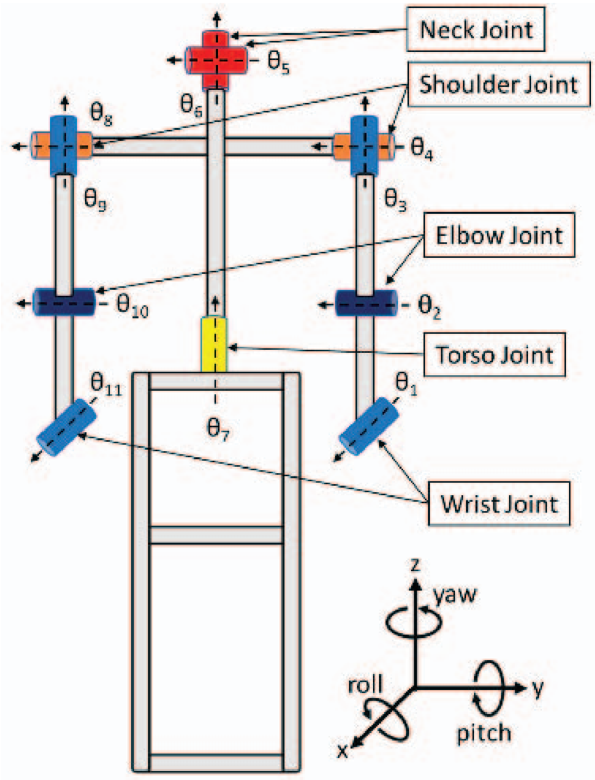


Fig. 2. SIBO Kinematic Model.

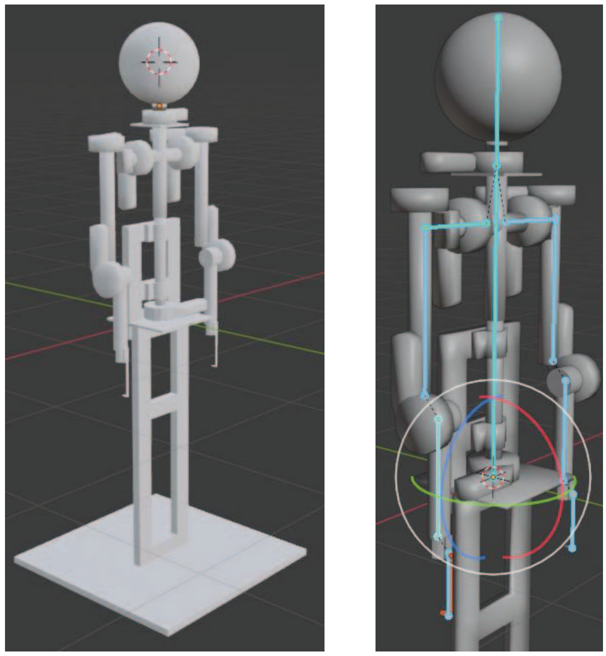
Performing a kinematic analysis on a robot before field implementation is essential [13]–[15]; therefore, Table 1 shows the SIBO degrees of freedom. We try to ensure that HUBO has sufficient degrees of freedom to mimic various forms of human movement, such as walking, shaking hands, and bowing. This robot has 11 DOF.

TABLE I. PARTS SPECIFICATIONS OF UPPER BODY

Part	DOF	Qty	Total	Range	
Wrist	1	2	2	θ_1	-40°≤ x ≤40°
				θ_{11}	-40°≤ x ≤40°
Elbow	1	2	2	θ_2	-90°≤ x ≤0°
				θ_{10}	-90°≤ x ≤0°
Shoulder	2	2	4	θ_3	-40°≤ x ≤90°
				θ_4	-120°≤ x ≤40°
				θ_8	-40°≤ x ≤90°
				θ_9	-120°≤ x ≤40°
Neck	2	1	2	θ_5	-30°≤ x ≤30°
				θ_6	-15°≤ x ≤30°
Torso	1	1	1	θ_7	-20°≤ x ≤20°
Upper Body DOF Total			11		

C. 3D Model Design

Before the robot is developed, it is necessary to estimate the dimensions and sizes of each module and avoid high costs due to trial and error (wasted material) when implementing directly in the field without simulation. In Fig. 2, the results of the SIBO 3D basic model design are shown. The rigging process or provision of bone is performed on this basic model so that the 3D model can be moved according to the joint planned in Table 1.



(a) (b)

Fig. 3. 3D CAD Model. (a) SIBO Basic Model; (b) Rigged Model

The 3D SIBO model given a bone is then tested by being given the pose/movement of 'Om Swastiastu' as one of Balinese local wisdom in interacting greetings between humans. The simulation results of the SIBO movement from the home position to 'Om Swastiastu' can be seen in Fig.3. Based on the simulation of movement and measurements on this 3D CAD model, the physical form of the SIBO robot in the real world is then made.

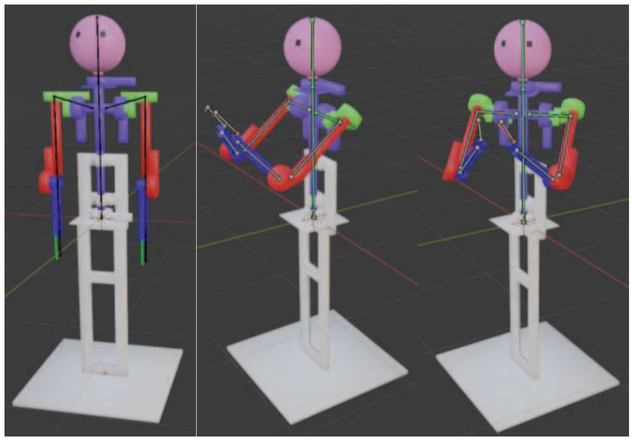


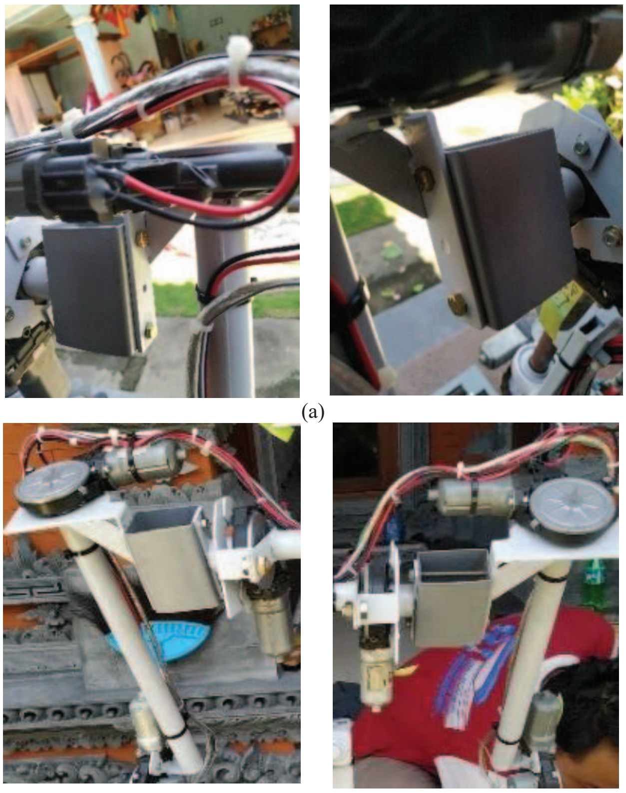
Fig. 4. Pose Mode to Simulate and Measure Robot Movement

IV. RESULTS AND DISCUSSION

After the movement simulation is complete, the next step is implementing the robot design. Several joints have been made and have been successfully tested for movement. The following are the details of the implementation of each joint.

The shoulder joint connects the arm to the rest of the body. There are two degrees of freedom at this joint. Each joint's driving unit is designed to lift the load from the upper arm, forearm, and wrist.

A. Shoulder Joint



(a)

(b)

Fig. 5. Two DOF Shoulder Joint Implementation. (a) Two DOF Shoulder Joint; (b) Shoulder Joint Left and Right

B. Elbow and Wrist Joint

(a) (b) (c) (d)

Fig. 6. One DOF Elbow Joint Implementation. (a) Elbow Left Arm; (b) Elbow Right Arm; (c) Wrist Left; (d) Wrist Right

The SIBO elbow joint has one degree of freedom. This joint connects the upper arm and forearm. A power window motor is used as the actuator in this joint. The wrist joint has one degree of freedom. The axis of rotation can move the wrist to the right and left. A Servo motor is used in this joint as an actuator because the load lifted is not too heavy.

The human neck has a complex kinematic structure. At SIBO, we use two degrees of freedom so that the head can rotate both right and left and up and down.

The SIBO torso has one degree of freedom with the angle of movement, as shown in Table 1. A motor power window is placed to move the torso, connected to a gear and two bearings as supports, as shown in Fig.7.

C. Neck Joint

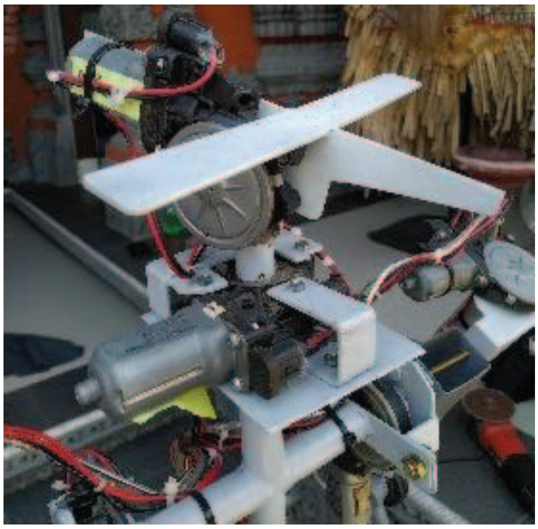
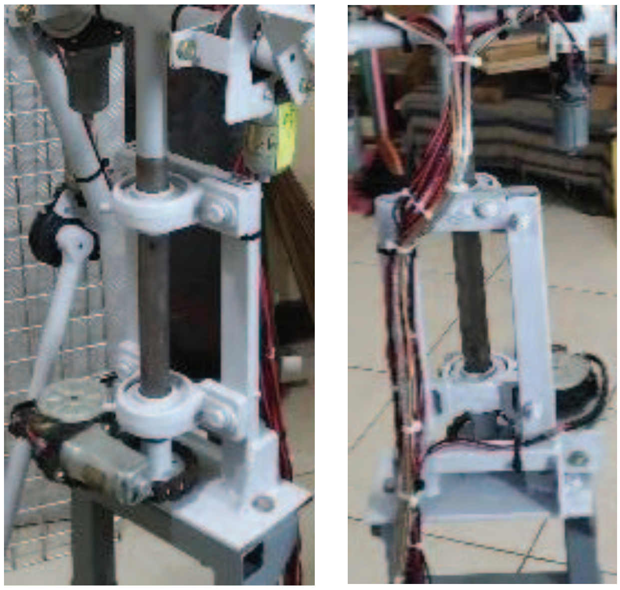


Fig. 7. Two DOF Neck Joint Implementation

D. Torso Joint



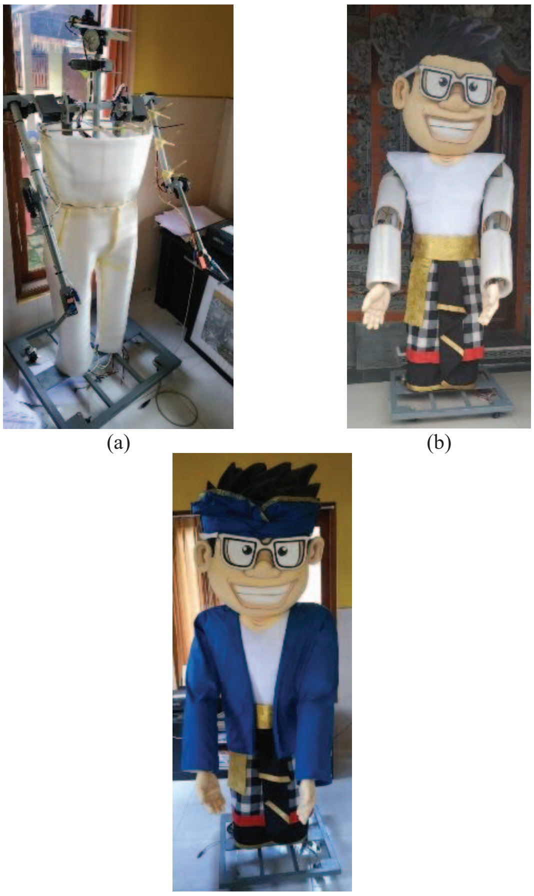
(a) (b)

Fig. 8. One DOF Torso Implementation

E. SIBO Casing

Making the casing on this robot uses the same technique as making ogoh-ogoh. Ogoh-ogoh is a typical Balinese culture in welcoming Nyepi day [16]. Some of the materials used are environmentally friendly in the form of woven bamboo and cloth. Fig. 9 shows the initial preparation stage when the robot frame is covered in a casing. Then at the half-finished stage, the shape of the case is visible. Some corners are given cavities to facilitate maintenance. At the same time, the final results can be seen in the Final Product stage.

We did a final test to test the movement of each joint imitating the pose/movement of 'Om Swastiastu'. The movement is carried out simultaneously to eleven joints. The results of the joint angle movement based on time can be seen in Fig. 10.



(a) (b)

(c)

Fig. 9. SIBO Casing Based on Balinese Traditional Culture. (a) Early Preparation; (b) Half-Finished; (c) Final Product.

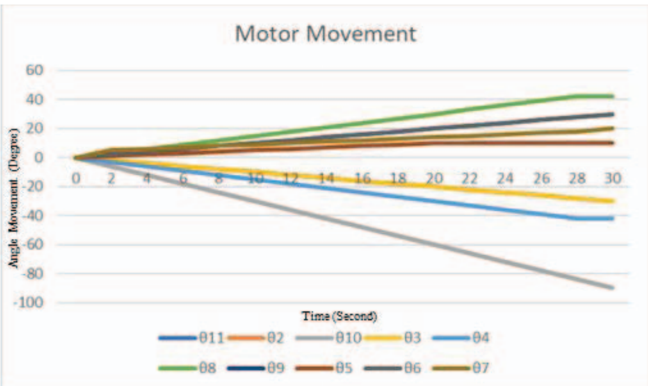


Fig. 10. Motor Movement Testing Using the 'Om Swastiastu' Pose

V. Conclusion

This article facilitated the cultural absorption of robotic technology, starting from the design stage to developing the new SIBO humanoid robot mechanic that can be used as a welcome guest. This robot has an 11-DOF upper body humanoid robot consisting of wrist, elbow, shoulder, neck, and torso joints. Further research still needs to be done to perfect SIBO by adding several encoders as sensors to read the robot's movement angle.

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