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BEEBARISTA: AUTOMATIC COFFEE MAKER ROBOT USING 6 DOF MANIPULATOR

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Abstract. *Most Indonesians like coffee drinks as an encouragement and meal during leisure time and working. Trend of robotic technology used in café/restaurant increased in Indonesia. In this research, we propose a coffee maker robot named BeeBarista using 6 DOF manipulator with simpler architecture for efficiency and low cost for productions. We developed a GUI program for tablet smartphone and algorithm for manipulator used in this system. This kind of robot can be used in restaurants, cafés, supermarkets, or offices. Based on the experiment, users easily order coffee, and the manipulator can give a cup to user correctly in 30 seconds from the time of order.*
Keywords: Coffee maker, Manipulator, Android, Arduino, AI, Smartphone

1. **Introduction.** Coffee is one of the drinks favored by Indonesians and the level of coffee consumption in Indonesia based on the survey in 2011 reached 800 grams/capita/year [1]. People enjoying coffee are influenced by several factors including the type of coffee, the method of serving, and the location. These three factors greatly influence a person to enjoy coffee. Therefore, we need an innovation from these three factors such as robots for making and delivering a cup of coffee.

Industrial robots, due to their great speed, precision, and cost-effectiveness in repetitive tasks, now tend to be used in place of human workers in automated manufacturing systems and restaurants. In restaurants or cafés, many people really want a coffee maker robot like baristas. Compared to humans, coffee maker robot can be attractive, smartly identify required refreshment orders, and work 24/7 without a payroll, thereby reducing additional manpower [2]. Many researchs of service robots in different application fields have been conducted such as assistive robot for elderly [3], robotic home assistant [4], robot waiters and coffee maker in restaurant [5,6]. For another example, the Cafelat "Robot" is a small, high quality manual coffee maker that makes delicious espresso. It uses few parts, no complicated electronics, and only premium materials like stainless steel – it is completely plastic free. Unfortunately, Cafelat is not a real robot, and the price is high [7]. Hwang et al. proposed robots that are taught through demonstrated actions to manipulate a coffee maker. Employing a Kinect RGB-D camera, the robot can obtain the coordinates of the objects and the corresponding moving trajectories, and the system is developed using deep learning architecture to recognize objects such as cups, and coffee capsules [8].

The main attraction of robotics is its promise of mechanical labor for the benefit of humans. Labor is typically performed by human arms powered by muscles and augmented using tools. It is therefore not a coincidence that the first widely commercialized industrial robots were robotic arms, also called robot manipulators [9].

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In this study, we propose a simple model of coffee maker robot using programmed actions for manipulator. Part I is an introduction, part II is preliminaries that explain about manipulator concept. After that, we discussed our method and experimental result and discussion.

2. Literature Review.

2.1. Arm manipulator. Kinematics is the study of the motion of objects without regard to the forces causing such motion. In kinematics, we study higher-order derivatives of position, velocity, acceleration, and position variables with respect to time or other variables. Robot arm kinematics is the transformation of coordinates (x, y, z) in the Cartesian system to the system of joints in the robot with coordinates of angle $(\theta_1, \theta_2, \theta_3, \theta_4)$ [9]. Conversion from Cartesian to the joint system is called *forward kinematics*, whereas the opposite conversion is called *inverse kinematics*. The forward kinematics of robot manipulators consist of computing the position and orientation of a robot end-effector when all the joint variables are known. The inverse kinematics problem requires finding one or more sets of joint values from a known end-effector pose.

A robotic manipulator is made up of rotational joints and linear joint/telescopic joints. The end-effector is any device intended to manipulate objects (magnetic, electric, or pneumatic grippers) or to transform them (tools, welding torches, paint guns, etc.). It constitutes the interface with which the robot interacts with its environment. An end-effector may be multipurpose, i.e., equipped with several devices each having different functions. When analyzing the kinematics of a robot, the first step is always to produce the forward kinematics equations that relate the known desired end-effector pose matrix $\mathbf{P}$ to the unknown joint values $(q_1, q_2, \ldots, q_n)$. Recall that for a revolute joint $q_i = \theta_i$, where for a prismatic joint $q_i = d_i$. For an n-joint robot, the forward kinematics equations in matrix form are

$$\mathbf{A}_1\mathbf{A}_2\mathbf{A}_3 \ldots \mathbf{A}_n = \mathbf{P} \tag{1}$$

where $\mathbf{A}_i = \mathbf{A}_i(q_i)$, a function of joint variable q_i, is the homogeneous matrix for link-frame F_i from link frame F_{i-1} and $\mathbf{P}$ is the end-effector pose. Robot manipulator kinematics is often referred to as a transform between Cartesian space and joint space [10]. A robot configuration is a vector of joint variables. The set of all such vectors is called the joint space or the configuration space of the robot. The joint space is the set of all vectors $\mathbf{q}$ formed by joint variable values. For a robot with n joints, $\mathbf{q} = [q_1, q_2, \ldots, q_n]^T$. The basic principle of 6 DOF manipulator is shown in Figure 1 (model of manipulator depends on the manufacturer).

2.2. myCobot manipulator. myCobot six-axis collaborative robot is a multi-functional and lightweight intelligent robotic arm designed and developed by Elephant Robotics used in our research. myCobot shares 6 high-performance servos in 6 joints with the advantages of fast response, small inertia, smooth rotation and stable torque. With a weight of 850 g, a payload of 250 g and an arm length of 350 mm, myCobot is compact but powerful, can not only be matched with a variety of end effectors to adapt to different kinds of application scenarios but also support the secondary development of multi-platforms software to meet the needs of various scenarios such as scientific research and education, smart home, and commercial applications [11]. Figure 2 shows the specification of the myCobot.

A reference frame can be described in terms of the relation of one coordinate system with respect to another. The reference frame includes the concepts of position and posture, which is a combination of these two concepts in most cases. The Denavit-Hartenberg parameter (DH parameter) of myCobot is the modified DH parameter, and the specific parameter values are shown in Table 1, and detailed information of the manipulator is shown in Figure 3. In DH parameter definition, the rotating joint n, set $0 = 0.0$, where the x axis is in the same direction, and select the origin position of the coordinate system (N) to satisfy $d = 0.0$.

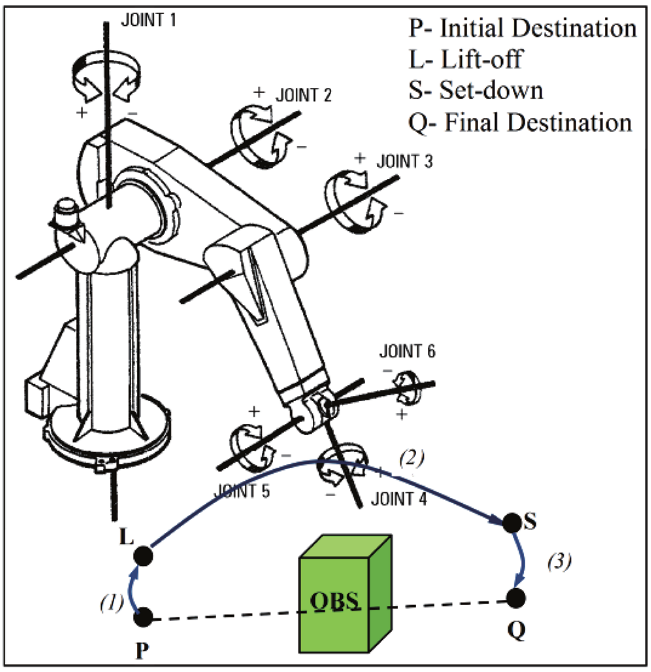

FIGURE 1. Basic principle of 6 DOF manipulator

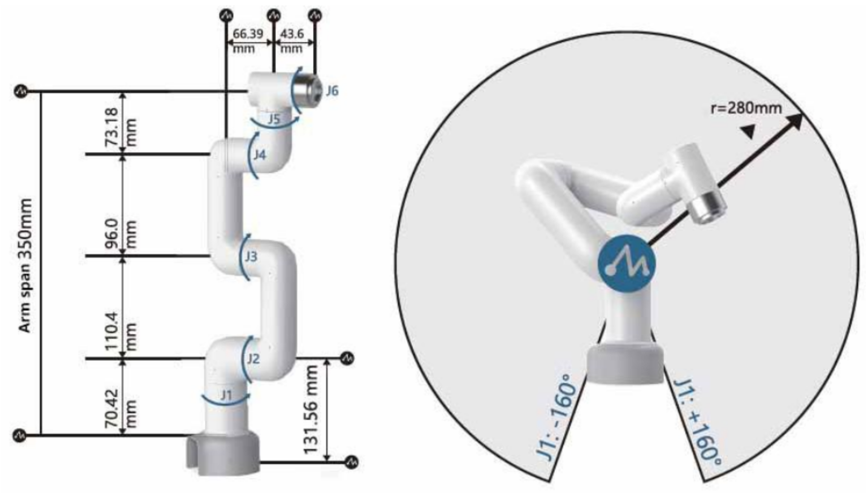

FIGURE 2. Arm span, joints, and parameters of myCobot manipulator [10]

TABLE 1. DH parameter of myCobot

Joint	Alpha	a	d	theta	offset
1	0	0	131.56	theta_1	0
2	PI/2	0	0	theta_2	−PI/2
3	0	−110.4	0	theta_3	0
4	0	−96	66.39	theta_4	−PI/2
5	PI/2	0	73.18	theta_5	PI/2
6	−PI/2	0	43.6	theta_6	0

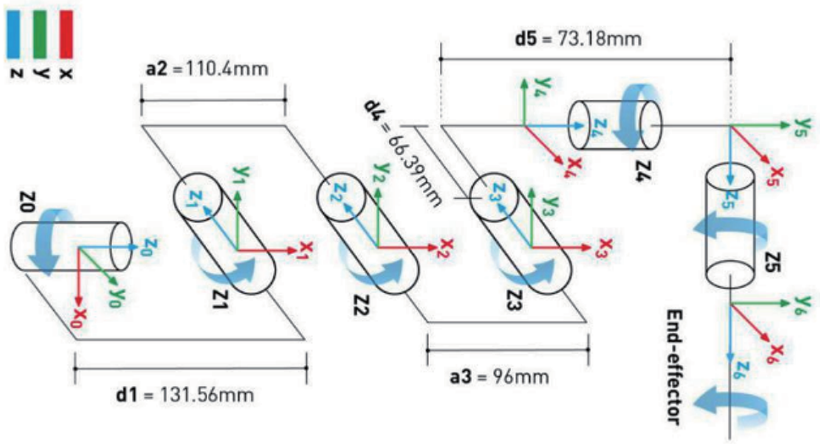

FIGURE 3. Detailed information of the manipulator and end-effector of myCobot

3. Proposed Method.

3.1. Architecture. Much research on manipulators focuses on how to control the movement of the arm using a camera. Robot arms are complex enough, with 5 or more DOFs, to precisely perform human tasks. However, simple systems are limited to hardcoded movements and cannot adapt to any change in the scope of the task. The system specification is dependent on the scope and the application [9]. For manipulator for coffee maker, robustness and easy to be operated is a main goal, so we make the manipulator simpler and use repetitive task based on the program developed use Arduino [12] and connection using Bluetooth HC-05. Wireless technology such as Bluetooth can be used for controlling devices. One of the most popular modules for research is HC-05. HC-05 is used for many applications like wireless headsets, game controllers, wireless mouse, wireless keyboard and many more consumer applications. It has range up to < 100 m which depends upon transmitter and receiver, atmosphere, geographic & urban conditions. It is IEEE 802.15.1 standardized protocol, through which one can build a wireless Personal Area Network (PAN). It uses Frequency-Hopping Spread Spectrum (FHSS) radio technology to send data over the air. This module can be used in a master or slave configuration [13]. The block diagram of the system is shown in Figure 4.

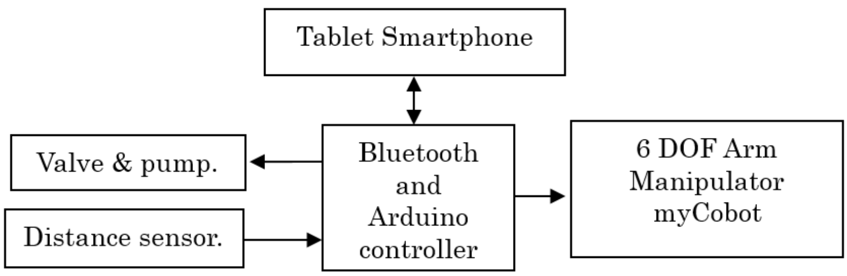

FIGURE 4. Architecture of coffee maker robot using tablet smartphone as an interface

3.2. Algorithm. The forward kinematics method uses kinematic equations to determine the joints of the robot so that the final coordinates of its movement can be determined. DH Parameter method is implemented on 4 variables that become parameters for analyzing the forward kinematics robot movement [14]. We use the library and example provided by myCobot, after which we improve the program. First, the program will make a connection with the smartphone using Bluetooth, and then accept commands from smartphone such as Latte, espresso and double latte as shown in Algorithm 1. For example, if user orders Coffee Latte, then the manipulator will take a cup and put it in the machine and then machine will process coffee, after that the manipulator will give a cup of coffee to the user then go back to initial position. The GUI of the application is using MIT App Inventor [15].

Algorithm 1. Coffee maker robot manipulator system

```
Declare variables.
configure input and output variables.
initialize manipulator.
make a connection with Bluetooth.
while (true)
begin
accept command from tablet smartphone
if order==espresso then
        take a cup
        make a coffee espresso.
        manipulator moves.
end if
if order==latte then
        make a coffee latte.
          manipulator moves.
activate pump and valve open.
end if
if order==double latte then
        take a cup
          make a coffee double latte
          activate pump and valve open.
          manipulator moves
          activate pump and valve open
end if
delay 3 seconds
call distance sensor
if distance > 10cm and If user takes a cup
        pickup==true
        if pickup==true then
        go back to initial position
        go back to initial position
end if
end
end while
```

4. **Experimental Result.** In our simulation, the coffee maker robot has only three available actions: first ask what the user wishes to do to infer his intention, the others do Coffee Espresso, Latte and Double Latte. The setting of myCobot as shown in Table 2.

We present the result of the experiment 10 times for each command, and the prototype is shown in Figure 5. The result of the experiment is shown in Table 3, which shows that

Table 2. myCobot's joint range of motion

J1	$-165 \sim +165$	J3	$-165 \sim +165$	J5	$-165 \sim +165$
J2	$-165 \sim +165$	J4	$-165 \sim +165$	J6	$-165 \sim +165$

Figure 5. Prototype of coffee maker robot using tablet smartphone and MIT App Inventor. Based on our experiment, the accuracy of movement from myCobot is better than other low-cost arm manipulators.

Table 3. Result of the experiment

No	Description	Action	Accuracy
1	Coffee Latte	Coffee Latte	100%
2	Espresso	Espresso	100%
3	Double Latte	Double Latte	100%

our system works properly. Based on user experience, this coffee making robot is quite interesting and easy to use.

5. **Conclusions.** Robotic system for brewing coffee is the latest technology trend working towards eliminating labor shortages and diminishing ever increasing workforce-related expenses. Unmanned cafés and bars, furnished with robotic arms or similar mechanisms are present today. In this paper, we introduced our coffee maker robot to deal with natural command from the tablet smartphone. Our system is a simple innovation and runs successfully for making a café/restaurant having a robotic for serving coffee to customer. For future research, improving the torque of manipulator and model of gripper is very important for handling higher load.

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