Practical Validation on Simulation of Multi Dobot Magician Trajectory Contour Tracking

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Keywords: Manipulator, Contour Tracking, ROS, Cooperative Control.

Abstract: Manipulators are arm-like robots that have been widely used in the industry to perform repetitive work usually performed by humans. The growing number of distributed control systems currently used by some modern industries is evident by research on cooperative control systems (CCS) where multiple entities is two or more things to achieve the same goal. A multi-agent system consists of many autonomous agents that can interact with each other or with their environment. The advantages of multi-agents system compared to single-agents are tasks that are performed more efficiently and increase the value of tolerance and flexibility in the execution of tasks. There is a problem that is doing research to prove the advantages of the system in manipulator robots. In this final task, a cooperative control system is performed on the manipulator robot, which is control of three manipulator robots in a group using virtual reality simulation with leader-follower concept. The manipulator that used is Dobot Magician which is a multifunctional robot arm for academic purposes. The platform used is Robot Operating System (ROS) and the simulator used is Gazebo. The results of this study are the realization of robot control through virtual reality, PID tuning with Ziegler-Nichols analysis method, precision value of each robot when performing compound control, as well as proofed by end-effector position value of all three manipulator robots. So the conclusion of cooperative control systems can be realized on the robot arm and the resulting precision value can prove the effectiveness of the robot in operation.

1 INTRODUCTION

Robot is defined according to the Robot Institute America (RIA) as a multifunctional manipulator that can be reprogrammed and designed to move materials, tools, parts or special devices through programmed movement variables to perform various tasks to help humans.

Md Rasedul Islam conducted research Cartesian trajectory based on Dobot robot control. Thing developed in this research, namely: use of DH Parameters and algebraic approach back kinematics. The controller used is PID, simulation is carried out in the Simulink environment in where the dynamic model of Dobot is simulated for follow the common space and space trajectory Cartesian. The results of this study are in the form of developing forward kinematics and reverse kinematics of the Dobot robot Magician. In this study the PID controller used to gain joint base control Dobot Magician robot (Md Rasedul Islam, 2019).

Qingsong Ai conducted research on the implementation of Dobot Magician's robotic arm trajectory control using the trajectory planning method. The results of this study show that the robot arm can write and draw correctly, and the upper computer interface of the control system can display the actual position of the arm tip in the real-time writing process, which has real-time stability and is good (Ai, Yang, Li, Feng, & Meng, 2018).

S Hernandez describes a concept of a Multi-master ROS system to present a multi-robot network system with each roscore node. This platform can generally be applied to both mobile robots and manipulator robots. In the ROS framework itself, there is already a solution regarding the system,

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namely multimaster_fkie which can build a ROS Network system configuration that involves two or more network devices (Juan, 2015) (Anggraeni, Defoort, Djemai, & Zuo, 2019).

Lehman (2015) explained about the introduction of the kinematics of mobile robots and manipulators using the features and tools found in the Robot Operating System (ROS). This study describes the kinematics used, such as inverse kinematics, forward kinematics, and DH Parameters that utilize the ROS feature (Yousuf, 2015).

The increasing prevalence of distributed control systems that are currently used by several modern industries, as evidenced by research on Cooperative Control Systems (CCS) where several entities, both two or more, do something to achieve the same goal. A multi-agent system is a system consisting of many autonomous agents that can interact with each other or with their environment. An example of a cooperative control system is a fleet of unmanned autonomous vehicles with a general purpose, such as reaching a target location. For example, automated forklifts can self-regulate to provide efficient service to machines on the warehouse floor (Monostori, et al., 2015) (Defoort, Floquet, & Kokosy, 2008).

The advantages of a multi-agent system compared to single-agent is tasks performed more efficiently and improve tolerance value and flexibility in implementation task. Based on these conclusions, then a problem arises, namely doing research to prove the superiority of the system on the manipulator robot. Robots that The robot arm used is Dobot Magician. In addition, this study used PID . control as an end-effector position control on the robot arm. Thus, this study able to do contour tracking using ROS (Robot Operating System) and end-effector position control using a leader-follower topology. Controller PID is used on the leader robot (Anggraeni, Defoort, Djemai, & Zuo, 2019) (Defoort, Polyakov, Demesure, Djemai, & Veluvolu, 2015).

The rest of this paper is organized as follows. The second section describes the mechanical specification design of Dobot Arm manipulator robot. While Robot Operating System (ROS) Simulator is discussed in the third section. The fourth section addresses the implementation validation and results. Finally, we conclude the article in the fifth section.

2 ROBOTIC ARM MANIPULATOR

In this section, description of Dobot Magician and Robot Operating System (ROS) are presented to the best illustrate the simulator.

2.1 Robotic Arm Dobot Magician

The robotic arm Dobot is a 3 DoF robot that has three stepper motors to actuate its joints (base, shoulder and elbow) as shown in Figure 1. The basic specification of robotic arm Dobot are shown in Figure 22.

Figure 1: Dobot Arm Robot.

The payload capacity of Dobot's end effector is 500 gram. The end-effector uses a servo motor and a pneumatic pump to deal with payload. The maximum distance that can be reached by Dobot is 320 mm. It can work under the temperature range -10°C to 60°C. The range of motion and maximum speed of each joints are shown in Table 1.

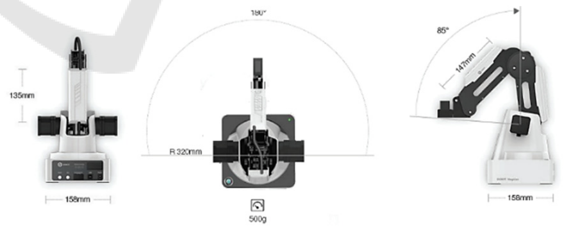

Figure 2: Dimension of Dobot Arm Robot.

Table 1: The Range of Motion and Max Speed of Each Joint.

Axis	Range	Max Speed (250g workload)
Joint 1 base	-135° to +135°	320° /s
Joint 2 rear arm	0° to +85°	320° /s
Joint 3 fore arm	-10° to +95°	320° /s
Joint 4 rotation servo	+90° to -90°	480° /s

3 ROS-BASED SIMULATOR

The manipulator system simulator is developed based on the open source ROS environment. The simulator is called ROS Gazebo.

3.1 System Modelling and Description

This section describes multi robots model inside ROS Gazebo Simulator. First Dobot Arm Robot profile must be set up as showed below and all model description stated in URDF,

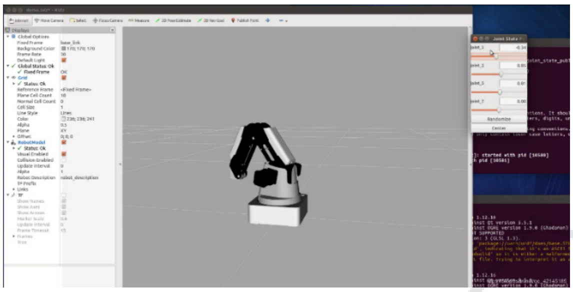

Figure 3: Dobot profile in Gazebo Simulator.

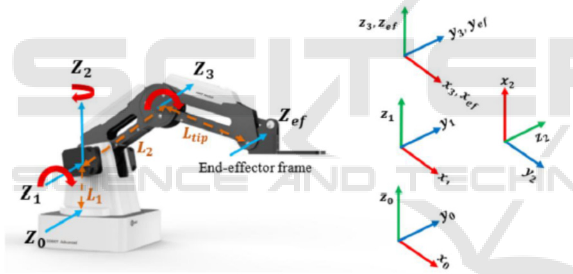

Figure 4: Dobot coordinate Frame.

3.2 Multi-Robotic Arm Manipulator Communication

To perform multi-robot movements, it requires a Multi-master ROS as a system capable of running Roscore more than two network devices. To use multimaster_fkie it is necessary to perform the installation on robot package in the following way:

```
git clone
https://github.com/fkie/multimaster_fki
e.git multimaster
rosdep update

rosdep install -i --as-root pip:false -
-reinstall --from-paths multimaster
```

In order for multimaster_fkie to be used, the mini-PC must have pre-installed Grpcio-tools.

Multimaster_fkie consists of two nodes that are executed master_discovery and master_sync. In general master_discovery send a multicast message to the network so that other ROS masters respond to other ROS masters and examine the local roscore for changes in the local network, and tell all other Master ROS in the public network this change.

Then, master_sync serves to process the information provided for the master_discovery node to register the topic and service to the local roscore. Information provided by the master_discovery node is also used to update information about topic and service. So it can be configured to select hosts, topics and services to use or ignore. By default all the topic and service of all hosts are synchronized, so as to reduce the bandwidth needed to synchronize various topic and service (Hock & Šedo, 2017).

```
$export ROS_MASTER_URI=http://<host
ip>:11311
```

ROS_MASTER_URI to determine which IP host will be the MASTER of its network. To launch package multimaster_fkie that need to be done is to do roscore first on each mini-PC.

```
$roscore
```

Then, launch the master_discovery node on each mini-PC by using the multicast _mcast_group argument.

```
$rosrun fkie_master_discovery
master_discovery
_mcast_group:=224.0.0.1
```

After launching master_discovery followed by a multicast sync that was covered by launching the master_sync node.

```
$rosrun fkie_master_sync master_sync
```

After performing synchronization on each of the mini-PCs, the master checks that have been included in the list_masters.

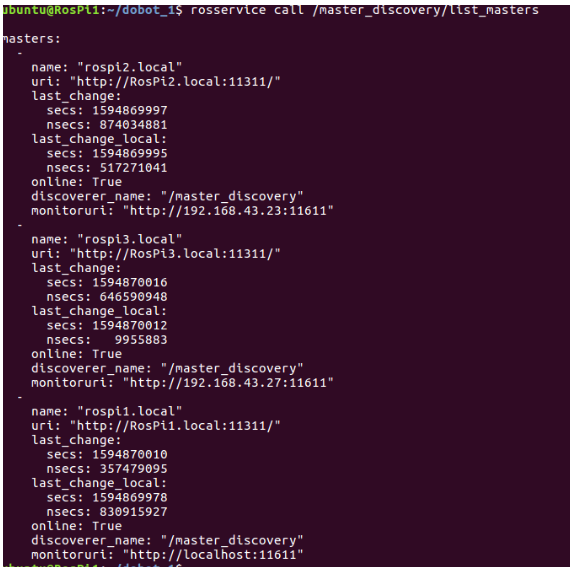

Figure 5: Multi Master Lists.

Here is the result of the Rqt-graph on ROS Multi-master:

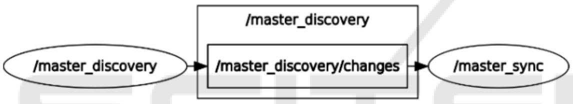

Figure 6: Rqt-Graph of Multimaster.

This rqt-graph shows the communication network established for multi robot application.

3.3 Robotic Arm Manipulator Contour Trajectory

The contour tracking involved follower 1 and follower 2. The executed followers is a topic that accepts positions based on the orders sent by the leader. Figure 7 shows a chart of contour trajectory:

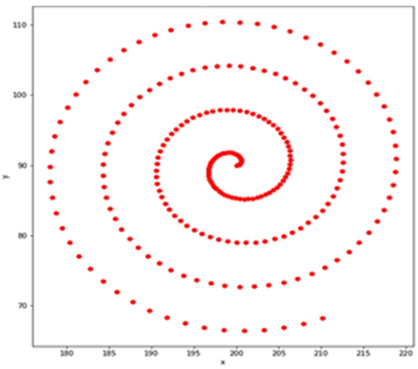

Figure 7: Calculation of publisher movement in xy graph.

Followers track the spiral contour tracking utilizing the X and Y coordinates. While Z is in static condition. The following is the calculation of the movement:

$$x = (l + t)X\cos(t) + 200$$
$$y = (l + t)\sin(t) + 90 \quad (1)$$
$$z = -30$$

The value of t is a change or time increase. In this case t increased by about 0.1 seconds so that if done rosbag file or recorded data, then it can be seen that the increase of time is followed by the subsequent movements.

Leader (Dobot 1) defined the contour trajectory and send the information of trajectory to follower 1 (Dobot 2) and follower 2 (Dobot 3). In order for the Masters of follower 1 and follower 2 to receive the information of trajectory from Leader, the use of ROS Multi-Master for Leader, follower 1 and follower 2 is connected to each other. Multi-robot contour trajectory has been conducted using Multi-Master ROS system.

4 IMPLEMENTATION VALIDATIONAND RESULTS

The simulation is a movement of a robot using a kinematics program for the 3 DoF robots and a new Gazebo movement limited to the joint movement.

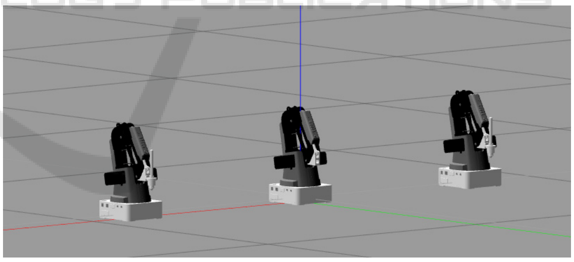

Figure 8: Simulation of Multiple Dobot.

Controlling the robot arm with PID tuning produces an ideal wave signal and the resulting value is the position value of the end-effector robot based on the coordinates achieved.

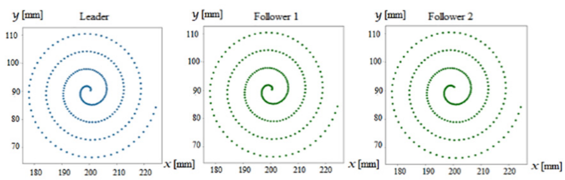

Figure 9: Lead-Follower Contour Tracking.

The following are the results of the movement of the three robots with Dobot 1 as the master which produces a certain contour trajectory, while Dobot 2 and Dobot 3 as followers follow the contour.

Table below shows the movement precision of each robot with X_1, X_2, X_3 as Dobot 1, Dobot 2 and Dobot 2 movement in X axis respectively. As well as Y_1, Y_2, Y_3 as Dobot 1, Dobot 2 and Dobot 3 movement in Y axis respectively.

Table 2: Precision Result in percentage (%) of Robot Movement.

T(s)	X_1	Y_1	X_2	Y_2	X_3	Y_3
0	0,085	0,390	0,083	0,315	0,049	0,371
0.1	0,074	0,417	0,064	0,335	0,062	0,390
0.2	0,060	0,434	0,090	0,347	0,106	0,401
0.3	0,043	0,442	0,128	0,350	0,172	0,402
0.4	0,025	0,439	0,187	0,346	0,240	0,394
Avg	**0,058**	**0,424**	**0,110**	**0,339**	**0,125**	**0,392**

Based on the data presented below, it is concluded that by using PID, the movement of the arm joint of the Dobot Magician robot is smoother but takes longer to reach steady state. It can be seen from the 1 axis Y joint, using PID control, the resulting system response is ideal. And if you pay attention to the three curves in one graph, robot 1 precedes the two robots that act as followers.

And the 3D contour tracking for all robots show as follow:

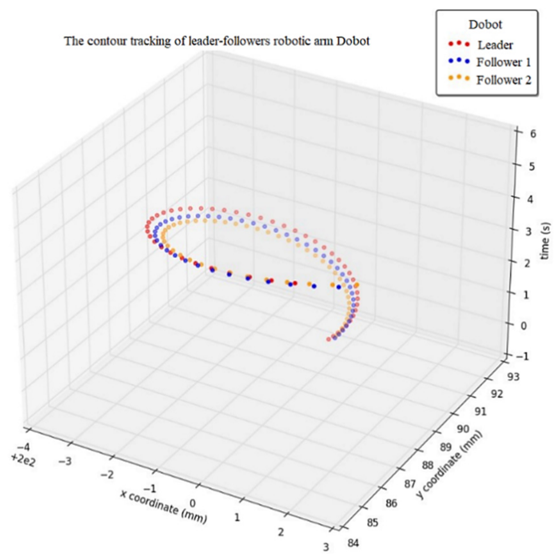

Figure 10: Lead-Follower 3D Contour Tracking.

5 CONCLUSIONS

The application of the Multi-Agent on the Dobot Magician robot arm produces movement with the concept of a leader-follower and the positioning accuracy and effectiveness in carrying out the work is precise as long as the movement carried out is still within the scope of the work area of the Dobot Magician robotic arm.

To control the robotic arm of Dobot Magician, the simulator used is the Gazebo Sim. So that the physical dynamics of the robot is also taken into account. The end-effector conditions in URDF are dummy or fixed.

The precision of the end-effector position on the Dobot Magician robot arm when doing contour tracking, it can be concluded that Robot 1 has a precision of 0.057% at the X coordinate and 0.42% at the Y coordinate, Robot 2 has a precision of 0.11% at the X coordinate and 0.424% at the Y-coordinate 0.338%, and then Robot 3 to its precision of 0.1257% at the X-coordinate and 0.39% at the Y-coordinate.

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