

# Design and Development of Multiple Mobile Manipulator Robots using Gazebo-ROS

P. Anggraeni

*Manufacturing Automation and  
Mechatronics Engineering Dept. Bandung  
Polytechnic of Manufacturing  
Bandung, Indonesia*  
pipit\_anggraeni@polman-bandung.ac.id

I. Rokhim

*Manufacturing Automation and  
Mechatronics Engineering Dept. Bandung  
Polytechnic of Manufacturing  
Bandung, Indonesia*  
ismail\_r@polman-bandung.ac.id

R. M. Salam

*Manufacturing Automation and  
Mechatronics Engineering Dept. Bandung  
Polytechnic of Manufacturing  
Bandung, Indonesia*  
roismujahiddin@gmail.com

**Abstract**—In this paper, multiple mobile manipulator is designed for handshaking system that is based on Robot Operating System (ROS). A mobile manipulator is a robotic manipulator arm mounted on mobile platform. The Festo Robotino mobile platform equipped with a robotic arm manipulator in order to extend the task of delivering goods and offers enhanced flexibility and agility, increasing the arm manipulator workspace by using the Festo Robotinos mobility. ROS is powerful tools which can be used in the field of robotics and Graphical User Interface (GUI) development. The Gazebo-ROS can be used to verify the coordination protocols of multiple mobile manipulator robot. Furthermore, some simulation and experimental results have shown the effectiveness of the designed multiple mobile manipulator robots

**Index Terms**—Mobile manipulators, Multiple Robot System, Robot Operating System (ROS), Gazebo Simulation

## I. INTRODUCTION

A mobile manipulator is a robot system construct from a robotic manipulator arm mounted on a mobile platform. The investigation of mobile manipulators has allured the attention of many researchers from the control, automation, and robotics society [1]–[4]. Such robot systems integrate the benefits of capability mobile platforms and agility of robotic manipulator arms so that increased the workspace and reduce their drawbacks.

Mobile manipulators plays an increasingly important role not only in industry applications such as assembly lines [5], logistics warehousing [6] and flexible manufacturing [7] but also domestic environments [8] such as opening doors [9] and assisted rehabilitation [10]. At the same time, new application scenarios are gradually emerging, for example, disinfection in medical institutions to ensure the safety of medical staff [11].

Robotics simulator has taken part in an important role in robotic development for the rapid validation of new prototype, algorithms, or applications [12]. The ability of robotics simulator to mimic the movement of robots and all objects in a virtual workspace without physically relying on the actual complete hardware system in industry, thus saving costs and time [13].

Robot Operating System (ROS) [1] has several packaged libraries and tools which aimed to create robot applications. There are numerous contributions from around the world. Gazebo [3] as a part of the Player Project is a 3D simulation which is designed to accurately reproduce the dynamic environments for the robot application scenes. There are some famous robots simulated in ROS and Gazebo platform, such as PR2, Care-O-bot, TurtleBot, etc. The ROS based Gazebo simulator is a powerful tool for robot simulation. However, there are some difficulties to run the simulator depend on the level of experiences.

The objective of this paper is to develop an effective Gazebo-ROS for multiple mobile manipulator with a simple and easy to use yet powerful simulator. The simulator is ideal for simulation of coordination behavior of multiple mobile manipulator as it can port directly to real robots, requiring little change to run real life testing in the future. The problems objectives consist of determining the communication for both the mobile platform and for the manipulators end-effector.

The rest of this paper is organized as follows. The second section describes the mechanical, electrical and ROS system design of the mobile manipulator robot while Gazebo-ROS simulation are discussed in the third section. The fourth section addresses the simulation results along the discussion. Finally, we conclude the article in the fifth section.

## II. MOBILE MANIPULATOR ROBOT DESIGN

This section presents the design of the mobile manipulator robot in the sense of the mechatronic system. This system is integrated with mechanical, electrical, and locomotion control. The design of the mobile manipulator robot has been expressed in the subsections below.

### A. Mechanical Design

Since a mobile manipulator robot consist of a mobile robot and a manipulator. Festo Robotino will be used as a mobile robot so that the mechanical design required is only the design of the robotic manipulator arm and its integration. In

this research, the manipulator was designed using 4 MG995 servo motors which function as 3 joints and one gripper. The mechanical designed for robotic manipulator arm is shown in Fig. 1

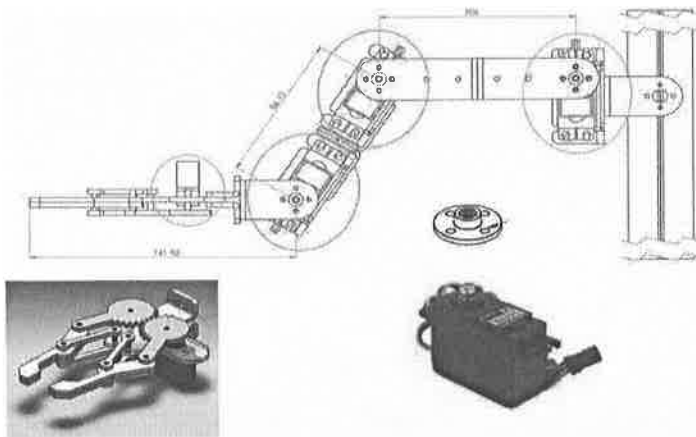


Fig. 1. The mechanical design of robotic manipulator arm

The manipulator is mounted on a lifter stand Robotino with the help of a small T-Slider that goes inside lifter mounting profile. Fig. 2 shows the manipulator already installed on Robotino.



Fig. 2. The robotic manipulator arm installed on Robotino mobile robot

### B. Electrical Design

Festo Robotino has been equipped with actuating systems as well as Analog Input, Digital Input and Digital Output terminal pins as shown in the Fig. 3. All these terminal pins designed for any external devices attached to Festo Robotino mobile robot. These digital I/Os could be used while an external manipulator attached for certain purpose.

The digital output terminals generate 24 VDC. However, the manipulator inputs require 4 6 VDC. Therefore, DC voltage converter needed to convert. This converter should



Fig. 3. Digital I/Os Festo Robotino mobile robot

convert to PWM with 0 20ms switching speed. In Fig. 4, the circuit convert from 24 VDC to 5 VDC using opto-coupler technology. The figure describes simply converting circuit for the above purpose.

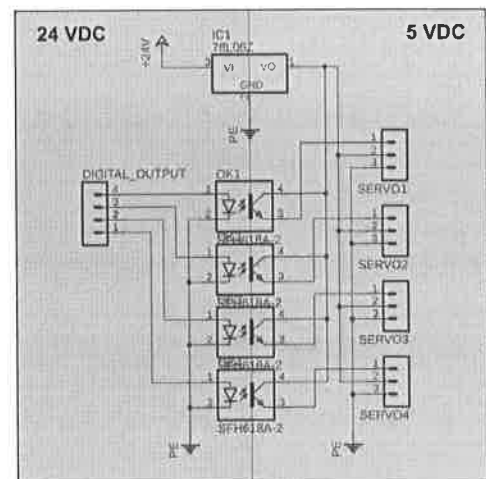


Fig. 4. Electric scheme for robotic manipulator arm

### C. ROS System Design

In robotic simulation using ROS, the general architecture can be rough classified into four key functional modules, i.e., modeling, kinematics, control, and visualization. The relationship of modules is illustrated as Fig. 5.

Robotino Festo has minicomputer as a controller using Ubuntu 16 operating systems and Robot Operating Systems (ROS) embedded. The simulation part displayed in the Gazebo GUI which is integrated in the ROS. Control program could be performed in the ROS using Python and C++.

Robotino with manipulator in the simulator controlled by Node Control consist of direct command to actuator. For manipulator, this command performed to each available joint. Node control also consist of equation that convert end effector position into joints angle with cinematic inversion. Fig. 6 describes relationship between Node in the ROS used for mobile manipulator robot.

Every joints position data and actual robot coordinate using odometry saved in the Node Robot Status. This node aimed

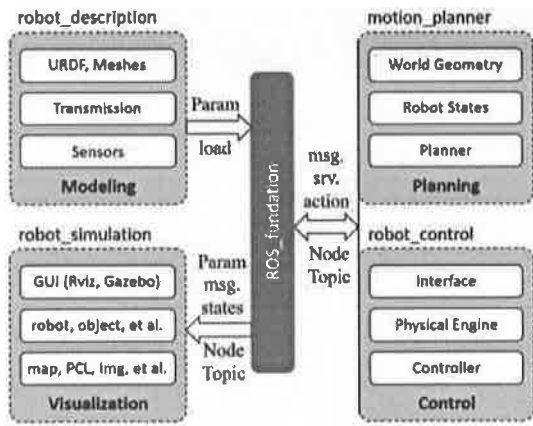


Fig. 5. General robotic simulation architecture and module relationship

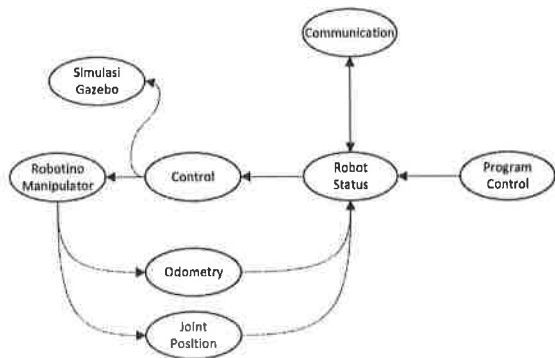


Fig. 6. Node connection design for mobile manipulator robot

to hold movement command to Node Control while moving to avoid commands collision. Node Communication aimed to collect several robot statuses. This node to inform ones robot status to another. Control program consist of program to generate command of robots movement.

### III. GAZEBO SIMULATION

To develop a multiple mobile manipulator using Gazebo ROS, it is required to install the multi master packages. The multimaster fkie allows two substantial nodes: the master discovery and the master sync nodes to run simultaneously. In our work, we employ the multi master communication platform to realize the procedures for developing multiple-mobile robots using ROS [14].

#### A. System Modeling and Description

The manipulator system can be modeling in tree structures. In ROS, an Unified Robot Description Format (URDF) is built to figure the system model configuration. URDF file is a XML specification recorded the whole physical information of link, joints, properties, actuators and sensors. As shown in Fig. 7, we create parts of manipulators urdf file.

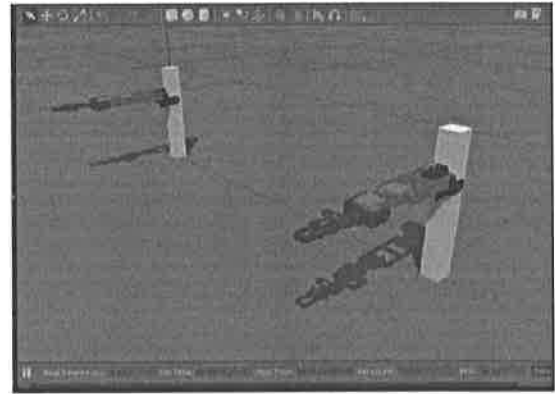


Fig. 7. Manipulator joint links urdf

Basically, URDF manipulator is made of five links and four joints. In Fig. 7, each link is represented in a different color. The design of each link is adjusted to the real shape, which consists of servo motor and bracket, so it must go through the CAD process first. Each form is designed using CAD software to adjust its original size to produce a 3D design file with the format. STL.

After obtaining the .STL design file on each link, the center point is adjusted using the MeshLab software. So that the .STL can be easily used when integrated into the URDF file. The final result of the process in the MeshLab software exported in a new format, namely .DAE. The goal is to embedded the file with more information when URDF is created, such as color and texture.

After all link designs are formed, a URDF file is created in XML containing the link and joint positions, the shape of each link, and the color for each link so that it looks like Fig. 7 if it is spawned in the Gazebo simulation view. The first joint is located on the base of the seat with the parent link world Gazebo.

Furthermore, the URDF manipulator must be combined with the URDF Festo Robotino to become a mobile manipulator. This combination is very simple because it utilizes the available URDF Festo Robotino. Just change the first parent link joint on the URDF manipulator, from world Gazebo to the Base Link on Festo Robotino. The position of the manipulator is at the front of the Festo Robotino. The result, can be seen in Fig. 8.

To implement the handshaking scenario, two mobile manipulators are needed, so in one world Gazebo the mobile manipulator must be spawned twice. By adding the namespace parameter to the URDF file, it is spawned twice with different namespaces so that two mobile manipulators of the same type can appear as in Fig. 9.

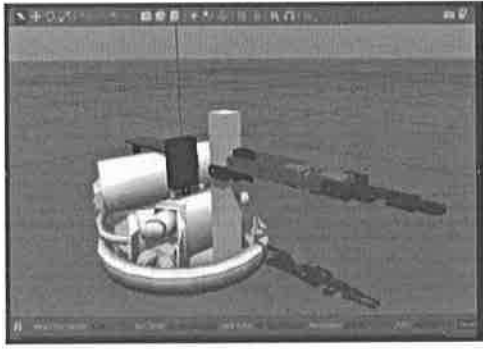


Fig. 8. Manipulator combined with Festo Robotino

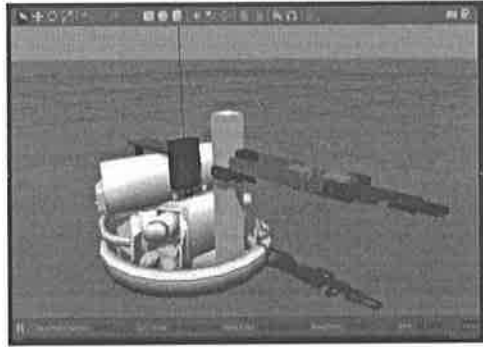


Fig. 9. Multiple mobile manipulator

### B. Planning and Algorithm Integration

To perform multi-robot movements, it requires a Multi-master ROS as a system capable of running Roscore more than two network devices. Fig. 10 shows the communication network for two mobile manipulators with one PC as workstation monitoring.

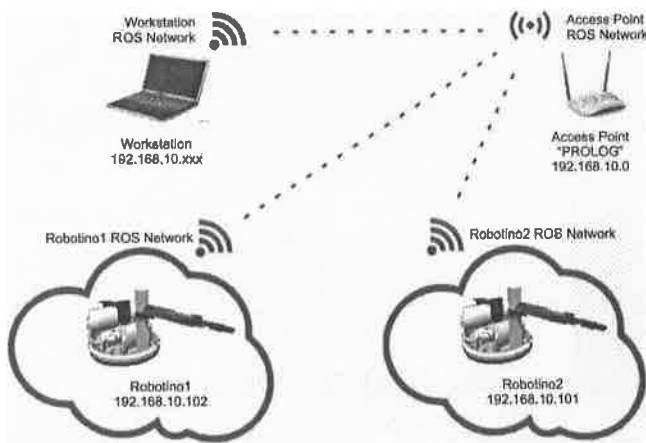


Fig. 10. Communication network for multiple mobile manipulators

In our study, we designed the communication network with one additional access point ROS network. All robots and PC workstation connected to this access point.

## IV. SIMULATION RESULTS

In this scenario, a mobile manipulator will carry an object from one point to another bounded by a transverse wall that is not so high that it cannot be passed. Therefore, we need another mobile manipulator that helps him across the wall to receive and resume objects brought to the destination point. Figure 11 shows the limitations of robot motion due to a barrier.

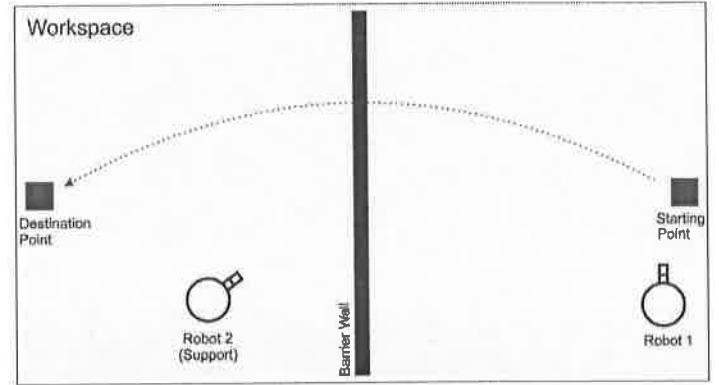


Fig. 11. Scenario Description

Fig. 12 shows the plot of trace results from manipulator simulation. The movement of the manipulator against the x-axis (horizontal) and z-axis (vertical). Orange color is the reference trajectory of manipulator, while the blue is the results from the topic/joint state in gazebo simulator of the other manipulator, representing the actual movement.

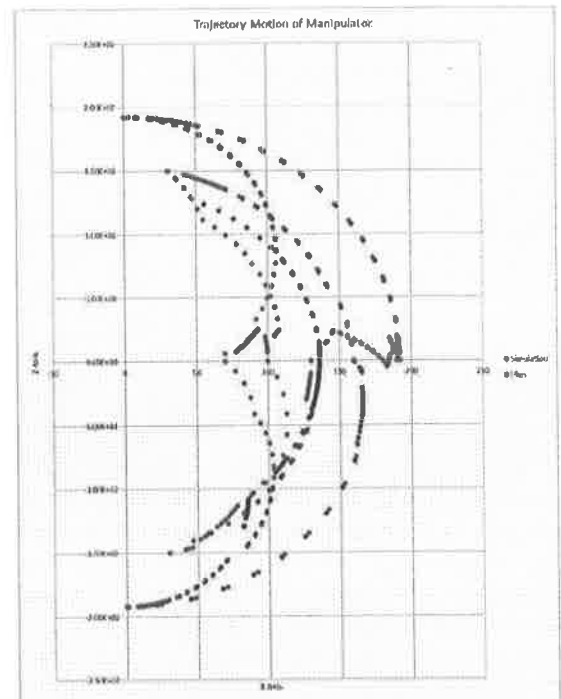


Fig. 12. The reference trajectory and the movement of manipulator

## V. CONCLUSION

The aim of this study is to develop a reliable environment for simulation and control of multiple mobile manipulator robots using the Gazebo-ROS software. The simulation in the form of URDF which is displayed on the Gazebo. For the future work with real robots, the Auction communication method will be implemented.

## REFERENCES

- [1]H. Deshpande, and J. Schleupen, Autonomous Mobile Manipulation Using ROS, in *Advances in Service and Industrial Robotics: Proceedings of the 26th International Conference on Robotics in Alpe-Adria-Danube Region, RAAD 2017* (Vol. 49, p. 389). Springer, July 2017.
- [2]R. Guzmán, R. Navarro, M. Cantero, and J. Ario, Robotnik professional service robotics applications with ros (2), in *Robot Operating System (ROS)* (pp. 419-447). Springer, Cham, 2017.
- [3]H. Deng, J. Xiong, and Z. Xia, Mobile manipulation task simulation using ROS with Moveit, in *2017 IEEE International Conference on Real-time Computing and Robotics (RCAR)* (pp. 612-616). IEEE, July 2017.
- [4]H. Zhang, Q. Sheng, Y. Sun, X. Sheng, Z. Xiong, and X. Zhu, A novel coordinated motion planner based on capability map for autonomous mobile manipulator. *Robotics and Autonomous Systems*, 2020, p.103554.
- [5]R. Bostelman, S. Fougou, S. Legowik, and T.H. Hong, Mobile manipulator performance measurement towards manufacturing assembly tasks, in *IFIP International Conference on Product Lifecycle Management* (pp. 411-420). Springer, Cham, July 2016.
- [6]M. Wise, M. Ferguson, D. King, E. Diehr, D. Dymesich, Fetch and freight: Standard platforms for service robot applications, in: *Workshop on Autonomous Mobile Service Robots*, 2016.
- [7]O. Madsen, S. Bgh, C. Schou, R.S. Andersen, J.S. Damgaard, M.R. Pedersen, V. Krger, Integration of mobile manipulators in an industrial production, *Ind. Robot: Int. J.* 42 (1) , 2015, pp. 1118.
- [8]B. Hamner, S. Koterba, J. Shi, R. Simmons, S. Singh, An autonomous mobile manipulator for assembly tasks, *Auton. Robots* 28 (1), 2010, pp. 131.
- [9]S. Chitta, B. Cohen, M. Likhachev, Planning for autonomous door opening with a mobile manipulator, in: *2010 IEEE International Conference on Robotics and Automation*, IEEE, 2010, pp. 17991806.
- [10]D. Park, Y.K. Kim, Z.M. Erickson, C.C. Kemp, Towards assistive feeding with a general-purpose mobile manipulator, 2016, arXiv preprint arXiv: 1605.07996.
- [11]A. Begi, Application of service robots for disinfection in medical institutions, in: *International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies*, Springer, 2017, pp. 10561065.
- [12]D. Portugal, L. Iocchi, and A. Farinelli, A. A ROS-based framework for simulation and benchmarking of multi-robot patrolling algorithms, in *Robot Operating System (ROS)* , Springer, Cham, 2019, pp. 3-28.
- [13]M. Aksu, J. L. Michaloski, and F. M. Proctor, Virtual experimental investigation for industrial robotics in gazebo environment, In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 52019, p. V002T02A071). American Society of Mechanical Engineers, November, 2018.
- [14]P. Anggraeni, M. Mrabet, M. Defoort, and M. Djemai, Development of a wireless communication platform for multiple-mobile robots using ROS, in *6th International Conference on Control Engineering and Information Technology (CEIT)* (pp. 1-6), October, 2018.