RoboCup Rescue 2023 Team Description Paper ROBIT

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Info

Team Name:	ROBIT
Team Institution:	Kwangwoon University
Team Country:	South Korea
Team Leader:	Baek InYup
Team URL:	https://robit.tistory.com
RoboCup Rescue TDP collection:	Pre 2019:

https://robocup-rescue.github.io/team_description_papers/

Team Qualifying Video:

- Maneuvering

https://youtu.be/Nxx_NP6fQFQ

- Mobility

https://youtu.be/sGhW3Kyv0ZM

Abstract— **This paper describes the overall structure and operation of KUBO2. ROBIT's intelligent robot team consists of seven undergraduate students at Kwangwoon University. Based on our experiences participating in three RoboCup Rescue Leagues (Canada RoboCup, Iran Open RoboCup, and France Online RoboCup) and the Korean Defense Robot Contest, we have developed and improved KUBO2. We participated in the 2022 Korean Defense Robot Contest and confirmed its excellent ability to overcome harsh terrain and perform missions through operator control. Therefore, we will make great efforts to demonstrate the robot's autonomous mission performance in this year's RoboCup Rescue League. In addition, we are currently developing control of manipulators, SLAM, and vision recognition.**

Index Terms—**RoboCup Rescue, Team Description Paper, ROBIT.**

I. INTRODUCTION

TEAM RO:BIT is a professional robot game team of Kwangwoon University in Republic of Korea, established in November 2006. For more than 10 years, we have been developing mobile manipulator platforms, robot arms, and self-driving robots. As a result, MK1(fig.2) and MK2(fig.3) for EOD mission, SJbot(fig.4, 5), the rescue robot that participated in world Robocup Rescue Robot League (2017 and 2018), RMP-1(fig.6) that won the 2019 National Defense Robot Competition, and RMP-2(fig.7) that was prepared for world Robocup Rescue Robot League (2020), were created.

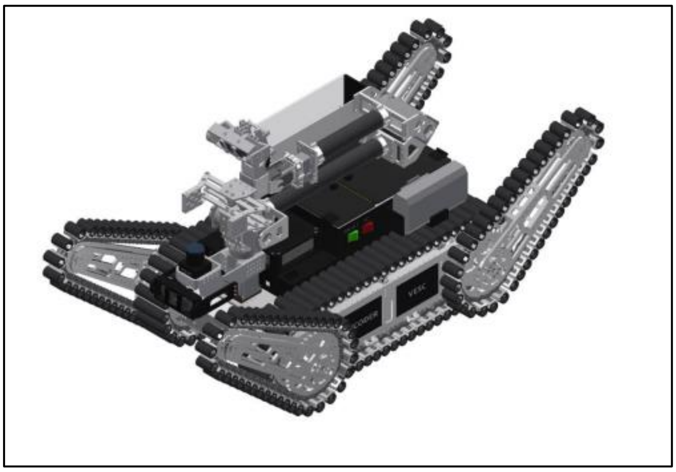

Fig.1 KUBO2

In 2021, Scue (Figure 8), which participated in the World Robocup Rescue Robot League (2021), and BangKukII (Figure 9), which won first place in the 2021 Defense Robot Competition, were created. In 2022, KUBO, which took second place in the defense robot competition, was produced by reflecting the experience and technology so far.

KUBO2, which has developed KUBO's manipulator performance and autonomous driving performance, is equipped with four cameras and a thermal imaging camera to assist in the search for victims and to process and integrate data to understand the situation. In addition, it will perform tasks such as mapping, localization, and navigation using LiDAR sensors, IMUs, and ROS.

Fig.2 MK1

Fig.3 MK2

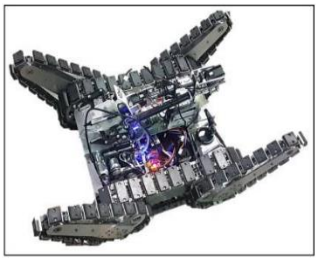

Fig.4 SJbot(2017)

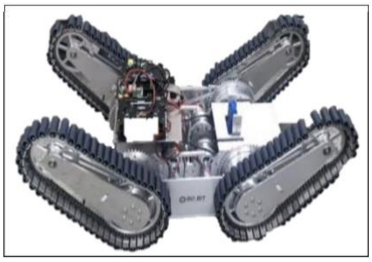

Fig.5 SJbot(2018)

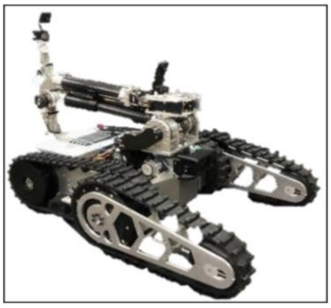

Fig.6 RMP-1

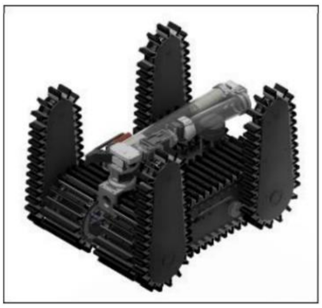

Fig.7 RMP-2

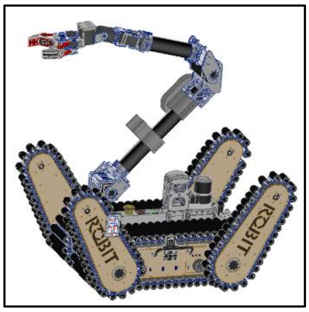

Fig.8 Scue

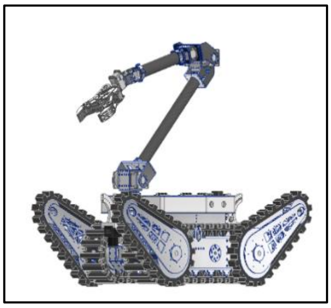

Fig.9 Bangkuk II

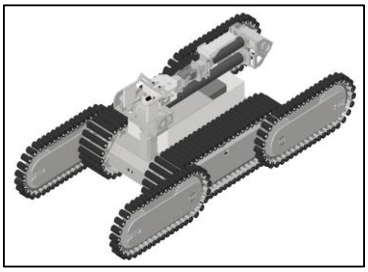

Fig.10 KUBO

A. *Improvements over Previous Contributions*

The robots that participated in the last competition had a lot of difficulty in carrying out their missions because the payload of the manipulator was weak and the motor power that drives the flipper was weak. The payload of the manipulator was solved by applying a self-made gravity compensation device, and in the case of the flipper motor, it was solved by changing from DC to BLDC and installing a reducer. In addition, the length of the flipper has been increased to overcome various terrains. Thanks to this, the robot's ability to perform missions has increased significantly. The size and weight of the robot were designed to be 577 * 700 * 520mm (horizontal * vertical * height with the flipper raised 90 degrees) and 76kg, respectively, to secure space inside the robot. This makes component placement and wiring more efficient and safer. In addition, due to increased accessibility, tasks such as battery replacement are easy.

II. SYSTEM DESCRIPTION

A. *Hardware*

The mobile base is powered by two BLDC motors for the main drive and four BLDC motors for the flipper operation. The previous robot used DC motors for the flipper operations, but due to a lack of torque, it was not possible to lift the robot, which became heavier than before. To solve this problem, each motor used for flipper operations was changed to a BLDC motor (MAX POWER: 1800W, TORQUE: 1.3NM) and a harmonic gear was used as a reducer. In addition, for the driving of the heavy robot, the BLDC motor of the main drive was changed to a BLDC motor (MAX POWER: 4000W, TORQUE: 3.8NM) with stronger power, and it also used the harmonic gear as a reducer. Accordingly, the power of the main drive motor increased by 220%, and the torque increased by 290%. As a result, it has a wider working radius, allowing it to perform more diverse tasks.

Fig.11.1 BLDC Motor

Fig.11.2 Reducer

<locomotion>

The chain with rubber blocks was used as a wheel. Using sprockets and chains instead of pulleys and rubber belts ensures to transmit reliable power and large torque.

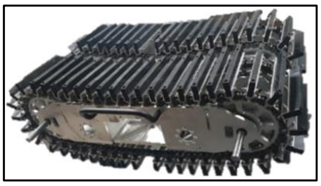

Fig.12 The Wheel Tracks

<power>

A total of 4 LiPo batteries 6 cells (4.2V per cell) are used to drive the robot. Two batteries are used to power the mobile base motors, and one battery is supplied to the circuit and connected in parallel to the motors of the manipulator, a LiDAR, and a router. The remaining one battery is supplied to the mini-PC. The power supplied to the motor of the mobile base is 25.2V, and the DYNAMIXELs of ROBOTIS used in the manipulator and PC are supplied with power after a voltage drop using DC to DC converters.

<electronics, including micro-controllers>

For motor control, it uses the Stm32F446re MCU, which is a stm32 chip from the Cortex-M4 series.

The development of the circuit is as follows.

1) Motor power control in MCU using a SSR (Solid State Relay) and boost circuit (3.3V to 5V)

2) Battery level measurement using a voltage divider circuit

3) Sensor value measurement of the encoder and infrared distance sensor

4) RS485 communication of PC to MCU and PC to DYNAMIXEL in the manipulator.

Fig.13 circuit

< manipulator>

To increase the payload of the manipulator, a self-made gravity compensation device using a spring was applied. As the gravity torque was compensated, the maximum load capacity increased to 6 kg, and when the manipulator was fully extended, the load capacity increased to 3 kg. The working radius of the manipulator is 1.2 m, and the end effector can reach a maximum of 1.66m when the robot is raised to the maximum using the flipper while connected to the mobile base. The manipulator has a high degree of freedom (6 DOF) and employs 6 Dynamixel, which are smart actuators with advantages for sophisticated work. The end effector uses Dynamixel, worm gears, and worm wheels to produce 10 times more torque than before. In addition, it can catch objects up to 120 mm, so there is no problem carrying out various missions.

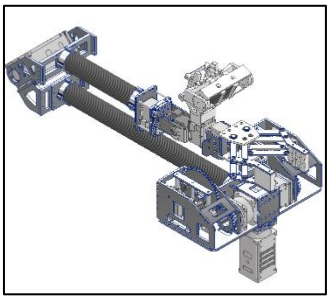

Fig.14.1 Manipulator

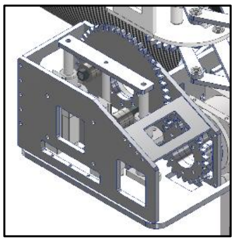

Fig.14.2 gravity compensation device

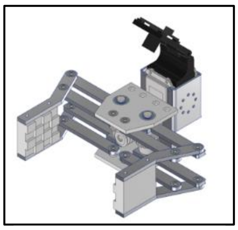

Fig.14.3.gripper

<sensors>

The following is a list of sensors attached to the robot. IMU for measuring the tilted state of the robot, and six encoders used for controlling the motors. In addition, there are PSD (Position Sensing Device) sensors, which are infrared distance sensors and LiDAR, used for autonomous missions, and USB cameras used for imaging. The aforementioned sensors and cameras are on the mobile base. A thermal imaging camera, two USB cameras, and a laser pointer will be used for the manipulator.

B. *Software*

<victim detection>

KUBO2 uses several types of sensors to determine situations and conditions and detect victims. Through image processing using OpenCV and Google Inception V3, motion, pattern, color, etc. can be detected. In addition, the victim's information can be collected from the image taken by the thermal imaging camera.

<mapping>

IMU, odometry, and LiDAR are used to identify the robot's own location. Simultaneously, it uses the SLAM library (Google cartographer) in ROS to create a 2D map and localizes itself.

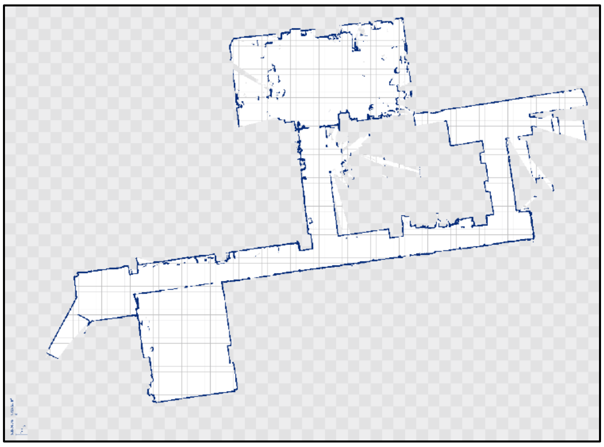

Fig.15 mapping

<motor control>

All actuators use a VESC for BLDC motor control and use a PID control method. In the case of a flipper, current PID control, speed PID control, and position PID control are used, and for the main drive, only speed PID control is used.

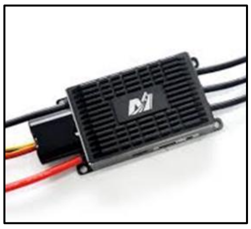

Fig.16 VESC

<arm control>

The basic init posture and grab posture of the manipulator are controlled through a macro using forward kinematics. If more detailed control is required to perform the mission, it is controlled through inverse kinematics using seven coordinate systems (the coordinate system of each axis and the base coordinate system).

<arm planning>

The A* algorithm is used to determine which trajectory the end effector of the robot arm will move on to reach a specific coordinate. Also, the robot arm is formulated as a skeleton model, and the base and flipper parts of the robot are represented as geometric models to prevent movement within the singularity range.

C. *Communication*

See Figure 17. Using the NEXT-870ap-2k, a Wi-Fi router with 5 GHz bandwidth, wireless communication is performed between the PC embedded in the robot and the operator PC. The communication standard is IEEE 802.11ac/a/n and the Udp/Ip protocol is used as the communication method. The device specification is POE IN, maximum 24V 0.5A, and the maximum power consumption will be within 12W. The transmission power to be used during the competition is about 19±2dBm and the antenna gain is 12dBi. "RRL ROBIT" will be the SSID we use.

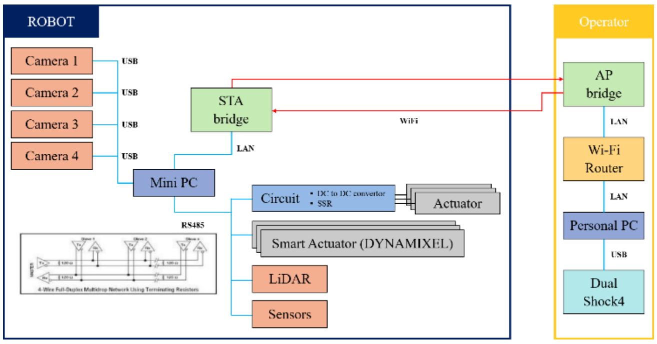

Fig.17 communication structure

D. Human-Robot Interface

Use the DualShock 4 and GUI buttons to control the robot. As shown in Figure 18, the operator can see the end effector of the robot, the mid-point of the robot arm (operator can see the movement of the gripper), and the front and rear views of the robot. The controller can grasp the overall posture of the robot through Gazebo simulation. The sensor data transmitted from the mini-PC inside the robot is displayed to the user in text format. Also, as the robot maps or navigates, R-Viz visualizes the map and the robot's path. The button and GUI configurations of the controller have been designed to be as intuitive as possible, allowing the controller to be easily adapted and controlled. In addition to the method directly controlled by the user, there is also a button to select tasks for the robot to perform missions autonomously.

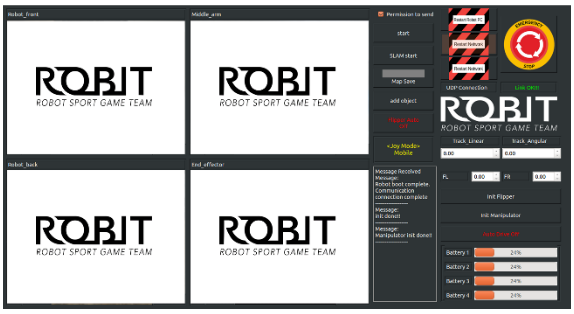

Fig.18-1 Human Interface

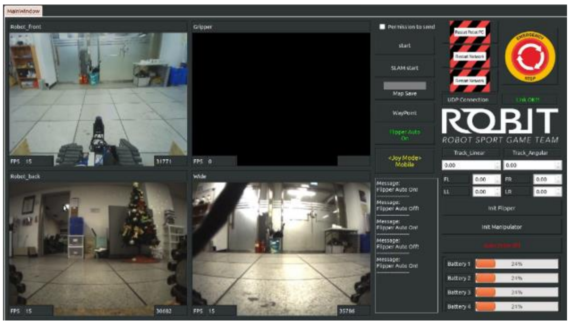

Fig.18-2 Real Situation

III. APPLICATION

A. *Set-up and Break-down*

For each mission, we use a mobile operator box to quickly set up the robot and make it easy to break-down. In this way, the setup is completed in about 3 minutes. The operator box consists of one laptop and two monitors, so it does not violate the regulations. In addition, the process (nodes) required for each mission is different, and there are many types of missions. Therefore, in order to avoid confusion, the mission will be efficiently performed by creating several UI buttons that activate only the nodes necessary for each mission. For the event of an emergency, in the case of hardware, the emergency power switch will be attached to the outside, and in the case of software, a large red UI button to respond quickly to an emergency.

B. *Mission Strategy*

Our strategy this year is to be as autonomous as possible. While participating in the National Defense Robot Contest, he experienced a case where the network did not work properly in an actual crisis situation. In such a case, it would be of great help if the robot could judge the situation and move on its own. Communication was often an issue, even in the environment of competition sites that reproduced disaster scenes. Therefore, we will construct a robot program that can interpret the information transmitted by the sensor and handle the situation without the operator's instructions as much as possible.

C. *Experiments*

Through the last defense robot competition, it was identified that it is possible to maneuver in slightly wet mud and grass. Afterwards, we planned to test the operation in the gravel and sand field environments. In addition, tests will be conducted on stairs of different heights using the laboratory's internal stairs and external marble. In addition to this, the wooden structures for each mission will be similarly manufactured and tested in the laboratory. These tests can also check the overall condition of the mobile base, such as whether power control is properly performed or communication between the operator PC and the robot is smooth. While making the structure, we are planning to make up for the lacking parts through simulation. Also, a test will be conducted to see if communication is performed smoothly even in a public place where many people and a complicated communication environment are intertwined, such as in a convention environment.

D. *Application in the Field*

KUBO2 is a robot that has improved several EOD and defense robots we have created. With improved torque in both the flippers of the mobile base and the manipulator, it can perform more diverse tasks than previous robots. It is designed to have excellent resistance to dirt by preventing foreign substances from entering the area and to protect parts such as motors and circuits from impacts. Therefore, we believe that this robot will be able to perform well in rescue activities in various terrains. We increased the number of batteries to operate the robot longer. In addition, as mentioned above, the torque of the manipulator is improved so that more varied tasks can be performed.

IV. CONCLUSION

We learned a lot from our last experience and developed KUBO2 through this. KUBO2 is more efficient, harder, and more intelligent because it complements previous problems. We expect 2023 Robocup Rescue to be a great opportunity to test our new technologies and learn how to improve our robots in a better direction. Even after this paper has been submitted, we will continue to strive to improve KUBO2 to perform better in searching and rescue missions. Therefore, in the actual competition, we are confident that KUBO2 is more advanced than described in TDP.

APPENDIX A

TEAM MEMBERS AND THEIR CONTRIBUTIONS

▪ Park KwangHyun	Supervisor
▪ Baek InYup	Team Leader
	SLAM, Navigation Algorithm
	Autonomous Driving Algorithm
▪ Baek JongWook	Manipulator Design
	Manipulator Control
▪ Koh WooBin	Electrical Design
	Communication Design
▪ Lee JiHaeng	Mobile Base Control
	Flipper Semi-Auto
▪ Lee MinSeok	Manipulator Axes Analysis
	Manipulator Simulation
▪ Lee MyeungJin	Communication Design
	Operator PC Setting
▪ Lee SeungHun	Mobile Base Design
	Vision Algorithm

APPENDIX B

CAD DRAWINGS

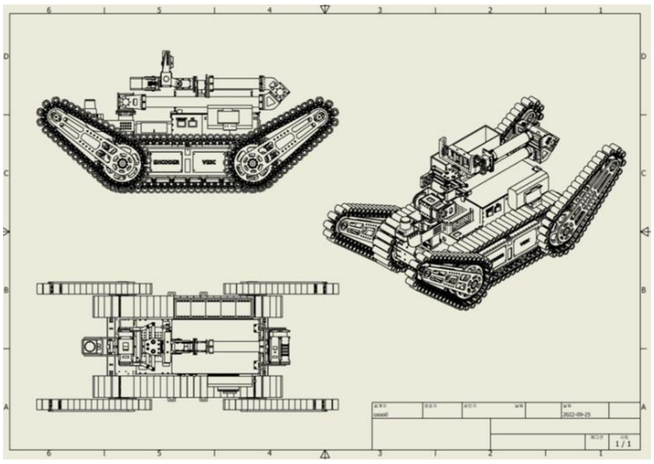

Fig.19 shows our KUBO2

APPENDIX C

LISTS

A. Systems List

The list of the robot system is shown in the following TABLE I

TABLE I

MANIPULATION SYSTEM

Attribute	Value
Name	KUBO2
Locomotion	Tracked
System Weight	76.2 kg
Weight including transportation case	90 kg
Transportation size	0.6 x 0.7 x 0.5 m
Typical operation size	1.5 x 1.0 x 1.0 m
Unpack and assembly time	90 min
Startup time (off to full operation)	5 min
Power consumption(idle/typical/max)	70 / 600 / ND W
Battery endurance(idle/normal/heavy load)	200 / 30 / ND min
Maximum speed(flat/outdoor/rubble pile)	1.0 / 1.0 / 0.8 m/s
Payload(typical/maximum)	3 / 6 kg
Arm : maximum operation height	1.2 m
Arm : payload at full extend	2 kg
Support : set of bat. Chargers total weight	2.8 kg
Support : set of bat. Chargers power	320 W (100-240V AC)
Support : Charge time batteries(80%/100%)	30 / 50 min
Support : Additional set of batteries weight	0.7 x 4 kg
Cost	$ 6000

B. Operator Station List

The list of the Operator Station is shown in the following TABLE II

TABLE II

OPERATOR STATION

Attribute	Value
Name	RobitOP
System Weight	5 kg
Weight including transportation case	5 kg
Transportation size	0.4 x 0.25 x 0.5 m
Typical operation size	0.4 x 0.25 x 0.5 m
Unpack and assembly time	1 min
Startup time (off to full operation)	5 min
Power consumption(idle/typical/max)	ND
Battery endurance(idle/normal/heavy load)	ND
Cost	$ 1000

C. *Hardware Components List*

The list of the Hardware Components is shown in the following TABLE III

TABLE III

HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num
Robot Structure	Aluminum	$ 540	-
Drive motors	APS 6384S	$ 134	2
	APS 5065	$ 93	4
Drive gears	Harmonic Drive (25-50-106205)	$ 1660	4
	Harmonic Drive (20-50-490811)	$ 1660	2
Drive encoders	AMT102-0048-N8000-W	$ 24	6
Motor drivers	VESC	$ 144	6
DC/DC	XL4016E1	$ 4	2
Batteries	Li-Po Battery 5000maH 6Sell	ND	4
Micro controller	STM32F446RE	$ 6	3
Computing Unit	Intel NUC	$ 580	1
IMU	EBIMU-9DOFV5-R2	$ 130	1
Cameras		-	-
USB Cameras	oCam-1CGN-U	$ 129	3
	Logitech C930	$ 124	1
Infrared Camera	Lepton V2	$ 368	1
LiDAR	HOKUYO UST-20LX	$ 2076	1
Battery Chargers	ND	-	4
6-axes Robot Arm	-	-	-
Structure	Aluminum, Carbon	$ 55	-
Smart Actuator	ROBOTIS PH54-200-S500-R	$ 2813	2
	ROBOTIS PM54-060-S250-R	$ 1708	1
	ROBOTIS MX-64AT	$ 283	3
	ROBOTIS MX-106AT	$ 417	1
Rugged Operator Laptop	ND	-	1

D. *Software List*

The list of the Software is shown in the following TABLE IV

TABLE IV

SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	18.04	Open	
ROS	Melodic	BSD	
OpenCV	3.4.0	BSD	LBP:Hazmat detection
Google Inseption V3	2.11.0	Apache 2.0	
Google Cartographer	2.0.0	Apache 2.0	2D SLAM

ACKNOWLEDGMENT

We would like to thank our academic advisor Kwang-Hyun Park and Kwangwoon Univ. for supports

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