RoboCup Rescue 2017 Team Description Paper NITRo

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Info

Team Name:	NITRo
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Team URL:	http://hi.web.nitech.ac.jp/

RoboCup Rescue 2017 TDP collection:
http://wiki.robocup.org/Robot_League

***Abstract*—Team NITRo has participated in the RoboCup Rescue Japan Open competition since 2012. The team consists of students at the Nagoya Institute of Technology, Japan. We will participate in RoboCup World Championship 2017 with a legged robot "GOLEG". Conventional type of rescue robots is trucked type. However, legged robot has potential to move and work in the disaster site like a human rescue worker. We test the performance of legged robot in rescue cite. Additionally, we introduce a novel teleoperation interface of legs "Virtual Marionette System". This paper describes about hardware and software of "GOLEG".**

***Index Terms*—RoboCup Rescue, Team Description Paper, Legged robot, User Interface.**

I. Introduction

OUR team, rescue robot team NITRo, consists of students of Nagoya Institute of Technology, Japan. Our adviser, Dr. Sato, was a member of a rescue robot team SHINOBI of the University of Electro-Communications and Kyoto University, when he was a student. He had participated RoboCup Rescue World Championship from 2003 to 2009. He won Best-in-Class Mobility Award at 2005 and 2006. Moreover, he got 1st place in Japan Open 2004 and 2009, and Best-in-Class Autonomy Award at Thailand Rescue Robot Championship 2010. Team NITRo has participated in the RoboCup Japan Open since 2012. Our tele-operated tracked robot as shown in Figure, called "NITRo-CRAWLER", got 2nd place in RoboCup Japan Open 2014. Our autonomous robot, called "ACCESS+", got 2nd place in the Best-in-Class Autonomy in RoboCup Japan Open 2015. We got 4th place in the Best-in-Class Mobility in RoboCup Japan Open 2016. Currently, we are developing a new tele-operated robot, called "GOLEG". GOLEG is a small legged robot having four legs as shown in Figure 1. We think that a legged robot can climb up a higher step than a tracked robot, if the sizes of robots are same. In addition, a legged robot has a potential to climb up a ladder and move on bad footing conditions such as the Sand/Grable Hills, because of its redundancy and its smallness of the ground contact area. Moreover, we introduce a novel user interface, called "Virtual Marionette System", for the teleoperation of our legged robot.[1][2] The operator can touch and move the CG model of the legs and the body of the virtual GOLEG in a virtual space by using a haptic devices. By using our user interface, the operator can operate the robot as if he touches its miniature directly. We would like to test the utility of our legged robot and the effectiveness of our proposed user interface in RoboCup World Championship 2017 Rescue Robot League. GOLEG has a manipulator for investigation and working. A camera, a thermal sensor, a CO2 sensor and a speaker are attached to the manipulator to gather information. In order to inform the operator where the robot is in the arena and to get points in the Exploration tasks, GOLEG has a laser scanner and creates a two-dimensional map using the SLAM (Simultaneous Localization and Mapping) technique.[3]

Robo Hero is with the Department of Robotics Gurus, Moon University, Moon, e-mail: .

J. Doe and J. Doe are with Anonymous University.

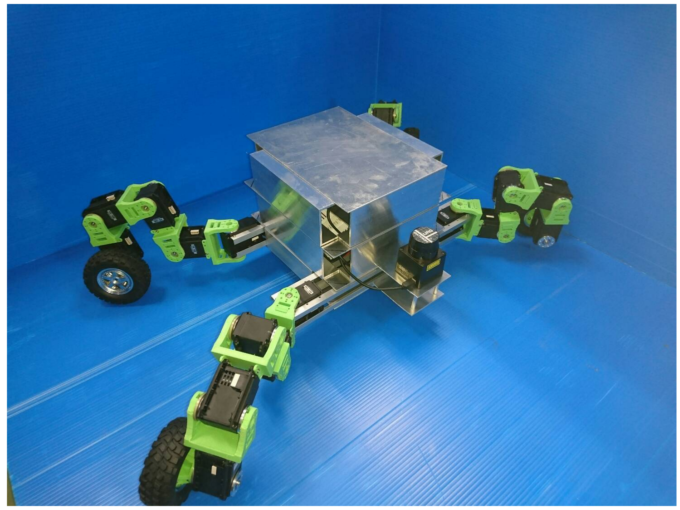

Fig. 1. Legged robot GOLEG (Prototype)

A. Hardware

1) Our Previous work: Our team has developed a tracked robot "NITRo-CRAWLER" since 2014 as shown in Figure 2. It has two main crawlers on the both sides of the body and four sub crawlers for running on the rough terrain. By using these crawlers, the robot can run on any kinds of terrains such as stairs and step fields. Some teams have developed this type robot. One of the standard configurations of rescue robots is this type of the crawler robot in these days.

2) Four-Legged Robot: For RoboCup Japan Open 2017 and World Championship 2017, our team is developing a four-

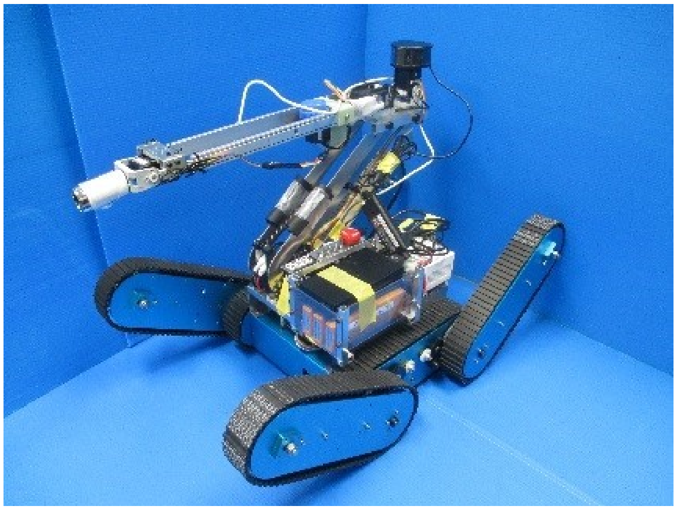

Fig. 2. Tracked robot NITRo-CLAWLER

legged robot, called “GOLEG”. The overview of the robot is shown in Figure 1. We think that a four-legged robot has advantages compared to a crawler robot as follows:

- Vertical movement on a ladder
- Walking over stepping-stones
- Striding over a high obstacle

However, in RoboCup Rescue Robot League, a legged robot is not used in almost all teams and could not get good scores. Our development of the legged robot is a challenge to overcome the weak points of a legged robot and to get better results than a crawler robot. Each leg of GOLEG has four degrees of freedom. Three motors rotate in pitch direction and the other motor rotates in yaw direction. Wheels are attached to each tip of the legs. On a flat ground, the robot moves using wheels. On a rough terrain, the robot will move with a crawling movement as shown in Figure 3, to decrease a risk of falling. Of course, if there is a high obstacle in front of the robot, the robot strides over it.

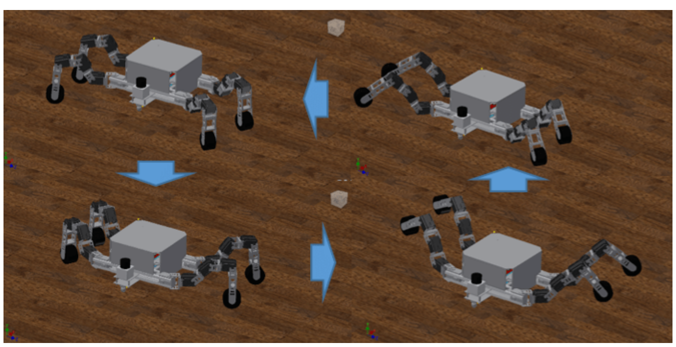

Fig. 3. Crawling movement of GOLEG

3) Manipulation System: A new manipulation system is also developing for RoboCup Japan Open 2017 and World Championship 2017. The overview of the new manipulator is shown in Figure 4. A camera, a thermal sensor, a CO_2 sensor and a speaker are attached to the manipulator to gather information. For the readiness test and the Dexterity Tasks, a gripper will be attached to the end effector of the manipulator.

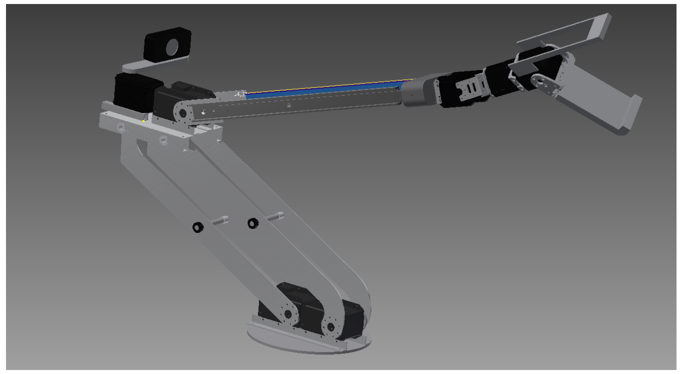

Fig. 4. Manipulator

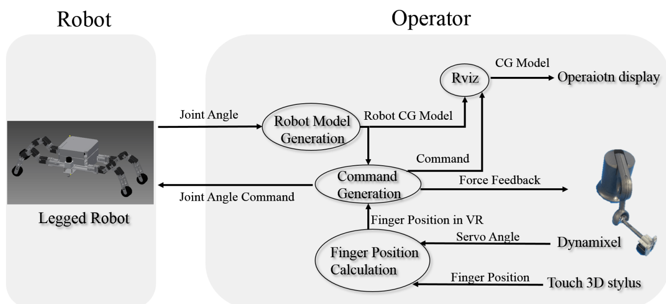

Fig. 5. System configuration of “Virtual Marionette System”

B. Software

All relevant software packages used by our team are listed in Table IV, given in Appendix C.

C. Communication

The communication method in our team is wired LAN to stabilize communication state.

D. Human-Robot Interface

When the robot crawls or runs with wheels, the operator inputs only the running direction by using a gamepad. However, it may be difficult to recover from the situation, for example, when one of the legs is caught in a groove. In such situation, the operator must operate each leg of the robot. In our previous study, a new user interface, called “Virtual Marionette System”, is proposed. [1][2] By using this user interface, the operator can grasp the each tip of the leg in a virtual space and change the posture of the virtual robot. After that, joints of the real robot are moved so that the posture of the real robot is similar to the virtual robot by using inverse kinematics. The system configuration and the overview of the user interface are shown in Figure 5 and Figure 6, respectively.

E. Mapping

We have used and improved Hector SLAM for the mapping. The map by SLAM is indicated in Figure 7. This map is generated in the final game of RoboCup Japan Open 2015. The red marks on the map indicate the position of victims. The tracks that robot passed through is also marked on the map.

Fig. 6. Overview of “Virtual Marionette System”

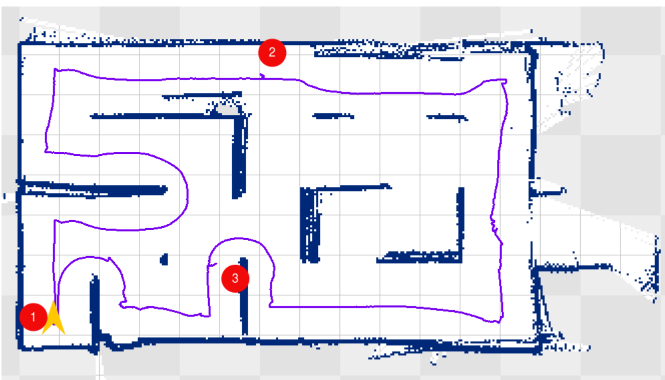

Fig. 7. Map generated in RoboCup Japan Open 2015

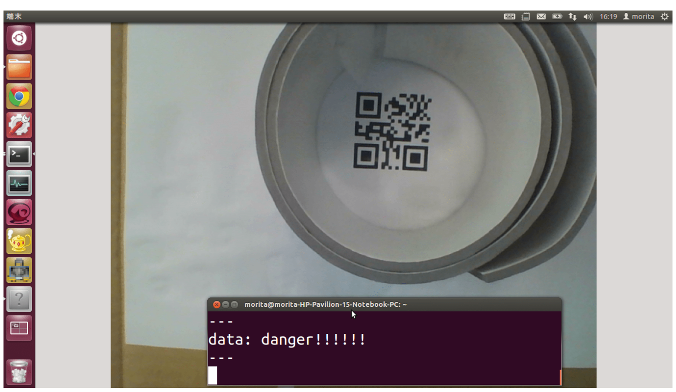

Fig. 8. QR code reader

F. Sensing

1) QR code reader: When a QR code appears on the image form the camera mounted on the manipulator, it is read automatically and information of the QR code is displayed on the PC monitor as shown in Figure 8.

2) Motion detection: Figure 9 is an image when the robot detects the motion of a victim. The motion is detected from a camera mounted on the manipulator.

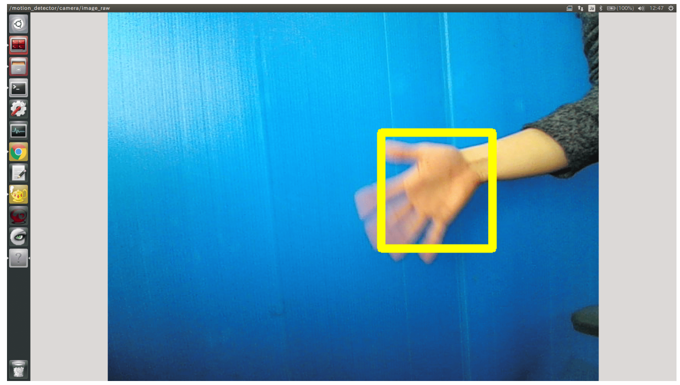

Fig. 9. Motion detection

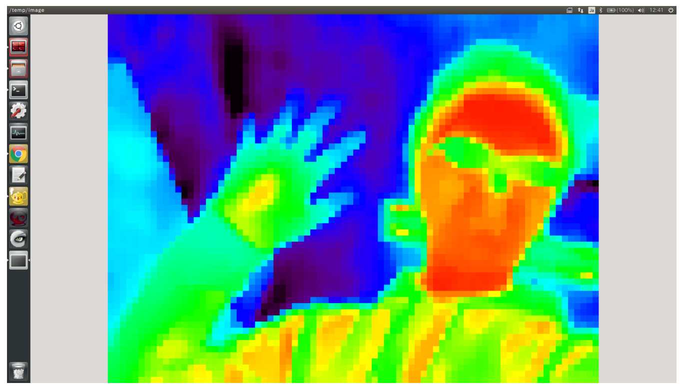

Fig. 10. Thermal sensor

3) Thermal sensor: Figure 10 shows thermal sensor vision. It is always displayed on the PC monitor with the camera image.

II. Application

A. Set-up and Break-Down

All the devices, which are necessary for the tele-operation, are stored in a Pelican case. The connection among the devices in the case is completed. Therefore, when the operator arrives at the operator station, he only connects one cable from the pelican case to the power supply, releases an emergency stop switch, and devices turn on. We use a wheeled dolly when carrying the robot. Therefore, our set-up and break-down methods are very simple and quick.

B. Mission Strategy

Our team would like to participate in the competition with a legged robot. The legged robot crawls on rough terrains, basically. On a flat ground, the robot uses the wheels to move fast. We plan to challenge all test suites of Maneuvering and Mobility, by utilizing the features of our legged robot. And we also plan to challenge to some tests of Dexterity and Exploration tasks. Moreover, we will install an algorithm for the robot to move autonomously, because we plan to use extra 5 minutes. And the robot is very small. Therefore, we would like to get prizes of “Autonomous robots class” and “Small Vertical Entry robots class”.

C. Experiments

Our team participated in the camp of RoboCup Japan Open 2016 Rescue Robot League with a prototype of the legged robot. We got lessons learned as follow.

- It is difficult to design the algorithm about the leg motion to move on rough terrains.
- The intuitive human intervention method is necessary to recover the robot when the robot become an emergency state.

Based on these lessons learned, we are developing the new legged robot and improving the operation system.

D. Application in the Field

We will learn more about the legged robot in this competition. We would like to utilize new knowledge for the development of the legged robot.

III. Conclusion

Our team will participate in RoboCup World Championship 2017 with a legged robot. Conventional type of rescue robots is a trucked type. However, we think that a legged robot may take the place of a tracked robot in the future, because a legged robot has potential to move and work in the disaster site like a human rescue worker. Therefore, we are developing a high-performance legged robot for Japan Open 2017 and World Championship 2017.

Appendix A
Team members and Their Contributions

- Ryo Asami — Mechanical design
- Makoto Kitani — Creeping algorithm
- Tomoki Yokotani — Manipulation
- Yamato Suzuki — SLAM algorithm
- Keiya Hoshino — Mechanic

Appendix B
CAD Drawing

The drawing of the robot is given in Figure 11.

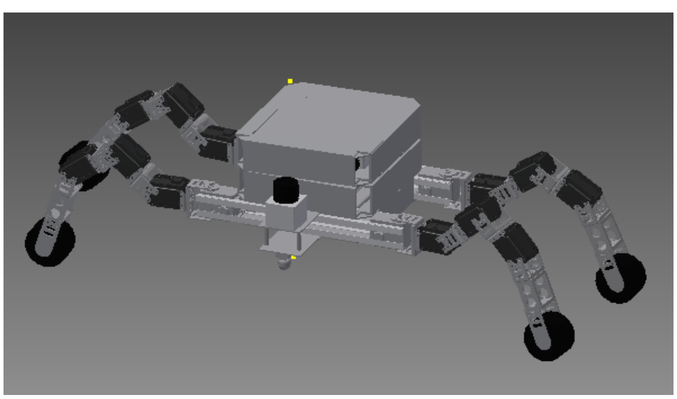

Fig. 11. CAD Drawing of GOLEG

TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	GOLEG
Locomotion	leg
System Weight	5kg
Weight including transportation case	10kg
Transportation size	0.5 x 0.6 x 0.4 m
Typical operation size	0.5 x 0.8 x 0.5 m
Unpack and assembly time	30 min
Startup time (off to full operation)	5 min
Power consumption (idle/ typical/ max)	20 / 50 / 100 W
Battery endurance (idle/ normal/ heavy load)	240 / 120 / 60 min
Maximum speed (flat/ outdoor/ rubble pile)	0.5 / 0.3 / 0.2 m/s
Payload (typical, maximum)	3/ 7 kg
Arm: maximum operation height	50 cm
Arm: payload at full extend	2kg
Support: set of bat. chargers total weight	0.8kg
Support: set of bat. chargers power	60W (100-240V AC)
Support: Charge time batteries (80%/ 100%)	90 / 120 min
Support: Additional set of batteries weight	1.4kg
Cost	8000 USD

TABLE II
OPERATOR STATION

Attribute	Value
Name	Virtual Marionette
System Weight	8kg
Weight including transportation case	20kg
Transportation size	0.8 x 0.5 x 0.3 m
Typical operation size	0.8 x 0.5 x 0.3 m
Unpack and assembly time	5 min
Startup time (off to full operation)	2 min
Power consumption (idle/ typical/ max)	100 / 200 / 300 W
Battery endurance (idle/ normal/ heavy load)	4 / 3 / 2 h
Cost	3000 USD

Appendix C
Lists

A. Systems List

B. Hardware Components List

C. Software List

References

[1] Y. Sawai, N. Sato, and Y. Morita, "Virtual master-slave system for teleoperation of rescue robot," in *16th SICE System Integration Divition*

TABLE III
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Drive motors	Robotis Dynamixel RX-28	USD 160	2
Drive motors	Robotis Dynamixel MX-64	USD 350	19
Drive motors	Robotis Dynamixel MX-106	USD 570	5
Battery Management	Self-made	USD 10	1
Motor batteries	HYPERION VX G3 LiPo PowerPack	USD 30	5
Robot PC batteries	ANKER 79AN7917	USD 22	2
Micro controller	Arduino	USD 15	1
Computing Unit	ECS LIVA-CO-2G-32G-W7	USD 170	1
WiFi Adapter	none		
IMU	none		
Cameras	BUFFALO BSW20KM11	USD 60	2
PTZ Camera	none		
Infrared Camera	none		
LRF	HOKUYO URG-04LX-UG01	USD 870	1
CO_2 Sensor	DFRobot SKU:SEN0159	USD 400	1
Microphone	BUFFELO BSHSM03BK	USD 3	1
Battery Chargers	HYPERION HP-EOS0606I-AD-C	USD 180	1
5-axis Robot Arm	Self-made	USD 1500	1
Rugged Operator Laptop	DELL PRECISION M6800	USD 1700	1

TABLE IV
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	14.04	open	
ROS	Indigo	BSD	
OpenCV	2.4.8	BSD	Victim detection
OpenCV	2.4.8	BSD	Hazmat detection
Hector SLAM	0.3.4	BSD	2D SLAM

Annual Conference, 2015.

[2] R. Asami, Y. Sawai, N. Sato, Y. Morita, T. Endo, and F. Matsuno, "Teleoperation system with virtual 3d diorama for moving operation of a tracked rescue robot," in *Advanced Mechatronic Systems (ICAMechS), 2016 International Conference on*, 2016.

[3] S. Kohlbrecher, J. Meyer, O. von Stryk, and U. Klingauf, "A flexible and scalable slam system with full 3d motion estimation," in *Proc. IEEE International Symposium on Safety, Security and Rescue Robotics*, 2011.