

RoboCup Rescue 2023 Team Description Paper

Quix

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Info

Team Name: Quix
 Team Institution: Tohoku University
 Team Country: Japan
 Team Leader: Shotaro Kojima

RoboCup Rescue TDP collection: 2019+:
<https://tdp.robocup.org/> Pre 2022:

Abstract—This paper describes a tracked vehicle "Onix", which has hole tracked body with four sub-tracks, and 6 degrees-of-freedom manipulator. We won World Robot Summit 2020 with this robot [1].

Index Terms—RoboCup Rescue

I. INTRODUCTION

QUIX is a team for search and rescue robot development, which consists of researchers and students at Tohoku University, Japan. Our team started in 2017, and the main participation results are as follows:

- RoboCup 2017 Nagoya: not qualified for finals
- RoboCup 2018 Montreal: 6th place
- World Robot Summit (WRS) 2018 Plant Disaster prevention challenge: not qualified for finals
- WRS 2020 Plant Disaster prevention challenge: **1st place**, METI minister's award, SCICE award
- RoboCup Rescue Japan Open 2022 :**1st place**, SCICE award

The main objective of our participation in RoboCup2022 is to test the capability of our new robot "Onix", as shown in Figure 1. Onix was developed to win World Robot Summit 2020, whereas we previously used quince [2] as a mobile base. Development of Onix was started in Aug. 2019 and completed in Oct. 2020. WRS 2020 was one year extended considering COVID-19's situation, and thus Onix was first used in the competition at WRS 2020 in Oct. 2021.



Table I shows the comparison between quince in RoboCup2018 and Onix in RoboCup2022. Onix was developed to increase the capability of the hardware, in terms of mobility, maximum velocity, and manipulator accessibility. The overall software structure is common between Onix and quince, whereas some parts are updated such as 3D mapping capability. The details of Onix's system configuration are described in the latter sections.

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Fig. 1. Tracked vehicle "Onix".

TABLE I
COMPARISON OF QUINCE IN 2018 AND ONIX IN 2022. HARDWARE WAS TOTALLY UPGRADED IN ONIX.

	Quince (in RoboCup2018)	Onix (in RoboCup2022)
		
Size [mm]	L700 × W500 × H450	L760 × W560 × H450
Weight [kg]	40	50
Sensors	visual cameras ×4 2D Lidar CO2 sensor Thermal camera	visual cameras ×5 3D Lidar CO2 sensor Thermal camera Depth camera (Real Sense)
Max. velocity [m/s]	0.4	0.9
Sub-track length [m]	0.3	0.5
Arm length [m]	0.8	1.4

II. SYSTEM DESCRIPTION

A. Hardware

Figure 1 shows the Robot's appearance, Table II shows features of the robot system, and Table III shows the features of the operator's station.

- locomotion

Onix has hole tracked body with four sub-tracks. sub-tracks are independently actuated as flippers so that the robot can traverse rough terrain actuating the flippers.

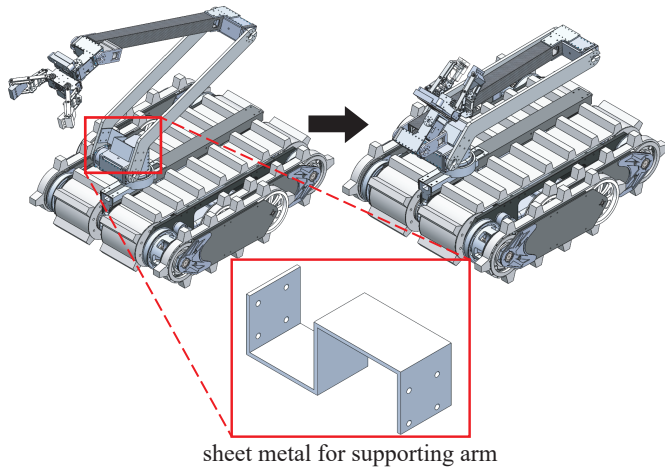


Fig. 2. Vehicle with folded arm. The manipulator can be compactly folded so that it does not reduce mobility when the robot traverses rough terrain.

The flipper length (0.5m) was extended compared to our previous robot (quince), in order to increase mobility on rough terrain. Along with that, sub-track actuators (Dynamixel, 24V, 200W) are upgraded to ensure that the robot can lift up the main body using extended sub-tracks. The main track's motors (Maxon, 32V, 200W) are also upgraded compared to quince, in order to increase the maximum velocity.

- manipulation Onix has a six DoF manipulator with a Chebyshev-link gripper. As shown in Figure. 2, This manipulator can be folded compactly during locomotion so as not to decrease mobility. Chebyshev-link gripper was adopted because of its linear trajectory during grasping motion as shown in Figure. 3, so that the operator doesn't have to adjust the distance to the grasping object considering its size.

B. Software

Fig. 4 shows the software configuration of Onix. The robot is operated from the operation station via Wi-Fi communication. In the robot, Intel's NUC computer with the core-i7 processor is used for the control unit, in which Ubuntu 20.04 operating system is used and ROS noetic is used for middleware. For the teleoperation of the chassis, fish-eye cameras are attached to the front and rear sides of the main body, and a spherical camera is attached to the elbow of the manipulator. Sensors for victim detection: a visual camera, depth camera (real sense), thermal camera, and CO2 sensor, are attached to the end-effector. A 3D laser scanning sensor (Robosense RS-Bpearl) is attached to the chassis for localization and mapping. In the operator station, a note PC is used for observing the sensor data including camera images, and for sending motion commands to the robot. Joystick is used for operating the chassis and the manipulator. The manipulator can be intuitively operated with an inverse kinematics solver (MoveIt [3]) so

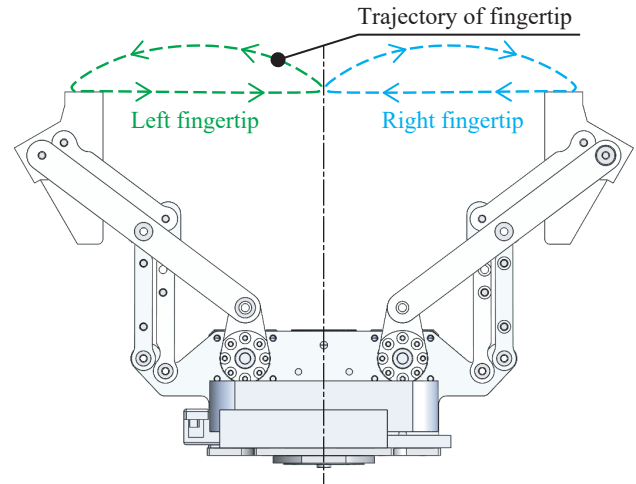


Fig. 3. Chebyshev linkage hand has a straight trajectory, which aids human operation With high accuracy

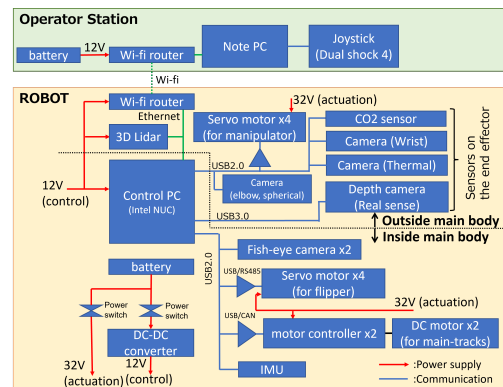


Fig. 4. System configuration of Onix. Red arrows show the power supply, blue lines show the USB connection, green lines show the ethernet connection, and yellow lines show serial communication.

that the operator just commands the motion direction in end-effector coordinate using a joystick.

C. Communication

5GHz Wifi or Ethernet cable are options for communication between the robot and the operator station.

D. Human-Robot Interface

Figure. 5 shows operation screen of onix. camera vision, robot's posture, and point cloud from raw Lidar data or SLAM results can be shown on this screen. The operator sends control commands to the robot via a joystick based on the information on this screen.

III. APPLICATION

A. Set-up and Break-Down

In order to shorten the set-up time, the following measures were taken:

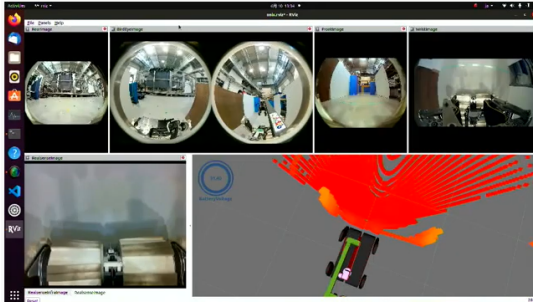


Fig. 5. Operation screen of Onix. camera vision, robot's posture, and point cloud from raw Lidar data or SLAM results can be shown on this screen.

TABLE II
ONIX: ROBOT SYSTEM

Attribute	Value
Name	Onix
Locomotion	tracked
System Weight	50kg
Weight including transportation case	60kg
Transportation size	0.76 x 0.56 x 0.45 m
Typical operation size	0.76 x 0.56 x 0.45 m
Unpack and assembly time	120 min
Startup time (off to full operation)	10 min
Power consumption (idle/ typical/ max)	100 / 200 / 400 W
Battery endurance (idle/ normal/ heavy load)	180 / 120 / 60 min
Maximum speed (flat/ outdoor/ rubble pile)	1 / 1 / 0.5 m/s
Payload (typical, maximum)	2/ 5 kg
Arm: maximum operation height	180 cm
Arm: payload at full extend	1kg

TABLE III
ONIX: OPERATOR STATION

Attribute	Value
System Weight	3.2kg
Weight including transportation case	5.0kg
Transportation size	0.4 x 0.3 x 0.25 m
Typical operation size	0.4 x 0.4 x 0.4 m
Unpack and assembly time	5 min
Startup time (off to full operation)	5 min
Power consumption (idle/ typical/ max)	30 / 40 / 60 W
Battery endurance (idle/ normal/ heavy load)	10 / 8 / 6 h

APPENDIX B LISTS

A. Qualification videos

The list of the qualification videos is shown below. We took this video for RoboCup2022 (remote).
 MAN, Center: <https://youtu.be/VMis9MCaHp0>
 MAN, Negotiate: <https://youtu.be/YI2mkl-15GA>
 MAN, Align: <https://youtu.be/MkKvx1A3hPA>
 MAN, Speed: <https://youtu.be/5MFuaxzHWfk>
 DEX, Linear touch/insert (60cm height): <https://www.youtube.com/watch?v=ijjyoK3U7jg>
 DEX, Linear extract/place (60cm height): <https://www.youtube.com/watch?v=guhKUHQBPE>
 DEX, Linear direct inspection (60cm height): <https://youtu.be/bTAJM1R6MPA>
 DEX, Strength (30cm height): <https://youtu.be/l4WR3gzPC7c>
 DEX, Shoring: <https://www.youtube.com/watch?v=KN5X8v8WscQ>

B. Systems List

See Table II and Table III.

C. Hardware Components List

See Table IV.

D. Software List

See Table V.

All equipment in the operator station can be powered by a mobile battery so that it can be carried with its power on.

All software components are executed with a single command.

B. Mission Strategy

In mobility tasks, high mobility due to hardware is utilized. In dexterity tasks, six DoF manipulator with inverse-kinematics based control is used for fast completion. In exploration tasks, the 3D map is constructed using 3D LIDAR.

C. Experiments

1) *Results in WRS2020*: Onix is already used in WRS 2020 and won 1st place. We tested tasks regarded to plant inspection (e.g. operating heavy valves, autonomous gauge reading), and now we are writing a journal article as a field report. Whereas, tasks regarded as disaster response (e.g. traversing on rubble, carrying heavy objects) are still not tested. We will test these items before the competition.

2) *Results in RoboCup Rescue JapanOpen 2022*:

IV. CONCLUSION

This paper described about team Quix and robot onix. Our motivation to participate in RoboCup2022 is to evaluate the new robot onix, which showed high performance in plant inspection tasks in WRS2020.

APPENDIX A

TEAM MEMBERS AND THEIR CONTRIBUTIONS

- Shotaro Kojima Team leader, robot operator, system integration
- Takaaki Nara Robot operator, system integration, electronics design, software (recognition)
- Tomoya Takahashi Mechanical design
- Ranulfo Bezerra Software (recognition)
- Kenta Gunji Software (recognition, SLAM, autonomous navigation)

TABLE IV
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Drive motors	Maxon Epos4Pole 50 200 W	JPY 140,900	2
Drive gears	Planetary Gearhead GP 42	included above	2
Drive encoder	Encoder ENC16 1024	included above	2
Motor drivers	EPOS4 compact 50/15	JPY 88,000	2
DC/DC	PAH300S24-12	-	1
Batteries	IDX DUO-C98	JPY 45,000	4
Computing Unit	intel NUC7i7DNKE	JPY 77,000	1
WiFi router	Asus RT-AX3000	JPY 20,000	1
IMU	BNO055 usb stick	JPY 5,000	1
Fish-eye Cameras	ELP 720p HD Wide Angle Camera	JPY 4,000	4
Spherical camera	Insta360 air	JPY 30,000	1
Thermal Camera	PureThermal2.0	JPY 22,000	1
3D LIDAR	Robosense RS-Bpearl	JPY 400,000	1
CO ₂ Sensor	omron environment sensor	JPY 12,000	1
High-torque servo motor	dynamixel H54-200-S500-R	JPY 360,000	7

TABLE V
ONIX:SOFTWARE LIST

Name	Version	Lisence	Usage
Ubuntu	20.04	open	OS for robot controller and operator station
ROS	noetic	BSD	Communication between software processes
OpenCV	4.2	BSD	image transport, recognition
Softwares for onix	1.0	closed	Motor control, operator interface, recognition, localization, and (semi-)autonomous operation

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