RoboCup Rescue 2016 Team Description Paper AIT Pickers

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Info

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***Abstract*—Several robots were dispatched when The Great East Japan Earthquake on March 11, 2011 . It was helped the exploration by having used a robot. Remote-controlled mobile robots are useful for searching around and inside buildings that have collapsed in a disaster. However, it took training period of the operation for about one month. We think that it is a difficult point to control an active sub-crawlers in one of the factors. Therefore, we research disaster response robots of the remote control type of simple operation system. "Scott I" has passive sub-crawlers. A robot with passive sub-crawlers is extremely simple operation. In addition, we introduced two systems newly. It is "the system which locates a position of victim on the environmental map" and "expansion mechanism for manipulator". This paper describes about hardware and software of "Scott I".**

***Index Terms*—RoboCup Rescue, Team Description Paper, passive sub-crawlers.**

I. Introduction

Our team is consisting of students of Aichi Institute of Technology. We do the participation to the Robocup for the first time. However, we participated in the RoboCup Japan Open three times from 2013 through 2015. Furthermore, our team won the Best in class Mobility of 2014, achieved two crowns by overall victory and the Best in class Mobility of 2015. We participate in the RoboCup for the purpose of the performance evaluation of the robot. We research "Scott I" for six years. We found a new task by participating in a competition. Our robot gets completion by review of the mechanism, and addition of a new system. However, I find a new task in this RoboCup to pursue a better robot and want to work on the task. We use "Scott I" of the Remote-controlled mobile robots in the RoboCup. "Scott I" aims at simple control. Passive adaptive sub-crawler is equipped in "Scott I". The crawler robot having a passive sub-crawler is operated only at a direction and run speed. However, a robot with passive sub crawlers can not recover from a situation from stuck. Therefore, the operator needs a technique that select the robot moving route. Accordingly, we use a "warning system". By the system, the current route selected by the operator is evaluated by calculating the stabilization for the robot in the roll and pitch directions before falling down. The system will be able to prompt the operator to select another route. "Scott I" mounts an investigation arm. We introduced to "expansion mechanism for manipulator" into a manipulator. Therefore, the range that "Scott I" could investigate became wide. Generally, gamepads are used for the operation of the investigation arm well. However, the burdens on operator increase when operate the arm by game pad, because the movement of the arm and button placement of gamepad are not relation. Therefore, we use slave system for arm operation. In the disaster site, it is expected that environment is unknown. In contrast, we make the environmental map using SLAM. The position of victim is expressed on an environmental map. We think that an efficient investigation is possible by making an environmental map.

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II. System Description

Figure 1 shows an overview of the "Scott I" crawler-type mobile robot.

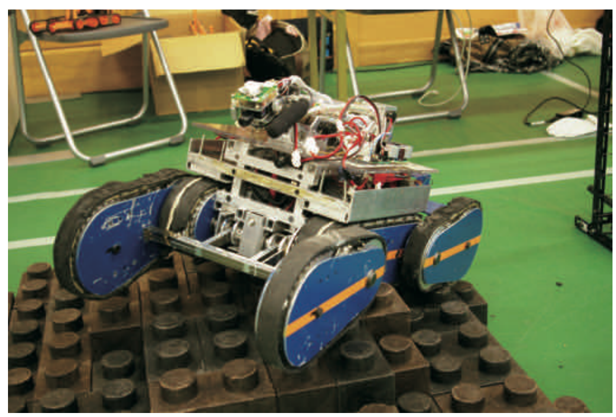

Fig. 1. Scott I

A. Hardware

1) Passive adaptive sub-crawler: The crawler robot with sub-crawler is installed several motors in order to control the rotational angle of sub-crawler. Each sub-crawler is possible to control actively by remote operation. Active sub-crawler have high mobility and good stability on the rubble. However, the hard training of operator is necessary for the purpose of mastering the complicated control method of active sub-crawler. Proposed method of semi-autonomous control law by Ohno et al. is the sequence control based sensor information. Note the frictional force of crawler, rotational direction is determined based the ground contact criterion, and the decide of driving speed is proposed. Compliance control method is proposed for the control of active sub-crawler angle in consideration of contact or impact of front/rear sub-crawler during getting over upward/downward step. By Yamazaki et al., the angle control that determined an target angle of front sub-crawler is proposed by using a laser range sensor. For rear sub-crawler, Normalized Energy Stability Margin is adopted in order to control of the robot's center of gravity. On the other hand, some crawler robot with passive mechanism is proposed.

Figure 2 shows a Scott of our robot has passivity in the joint part of the sub-crawler. "Scott I" has two main crawler and four sub-crawlers (front - 2, rear - 2). Figure 3 shows the sequence when a crawler-type robot with passive sub-crawlers traverses a simple step..

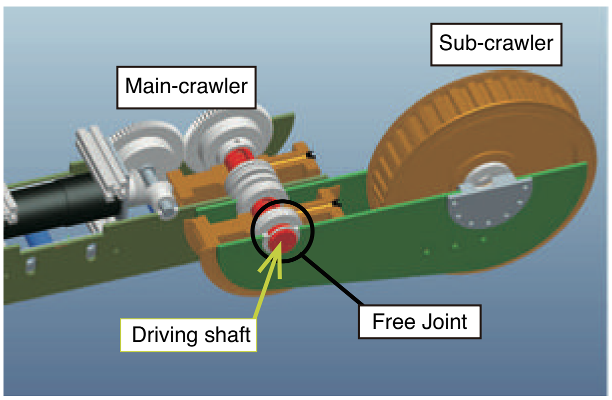

Fig. 2. Sectional View of sub-crawler

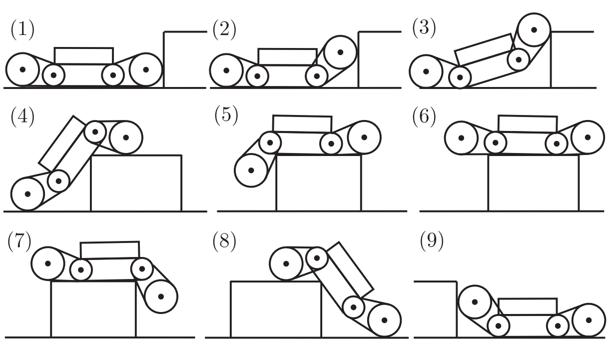

Fig. 3. Sequence for traversing simple step for crawler-type mobile robot with passive sub-crawlers.

For irregular road surface, sub-crawler rise by power to occur because of the driving force of the robot. The sequence of upward direction show in Figure 4.

Show in Figure 5, sub crawler is turn in the direction to down by the weight of itself. Therefore, travel for uneven terrain is possible only operating by movement speed and direction. However, sub-crawler is confirmed that it cannot contact with a road surface when sub-crawler turns at a big angle, and it cannot climb the step if a movable range of sub-crawler is small. There is the control method of angle restriction for the passive sub-crawler, it is different from the control of active sub-crawler. Because angle conditions of sub-crawler are different in traversing on uneven terrain

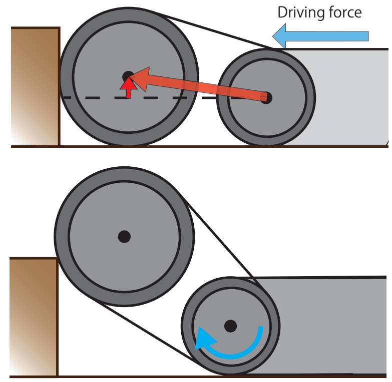

Fig. 4. Sequence in which the sub-crawler is movable in an upward direction

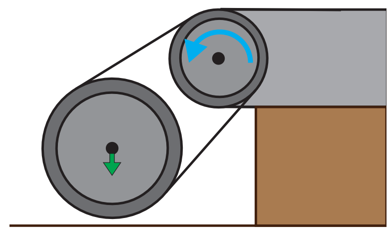

Fig. 5. Sequence in which the sub-crawler moving in a downward direction

Therefore, Scott has mechanism to restrict the sub-crawler angle. This mechanism is possible to change operation the movable range of the sub-crawler. Show in Figure 6, a variable angle restriction mechanism is adapted to the change of the angle depending on road surface environment. In addition, the robot can restore from stack. Figure 7 shows the space where

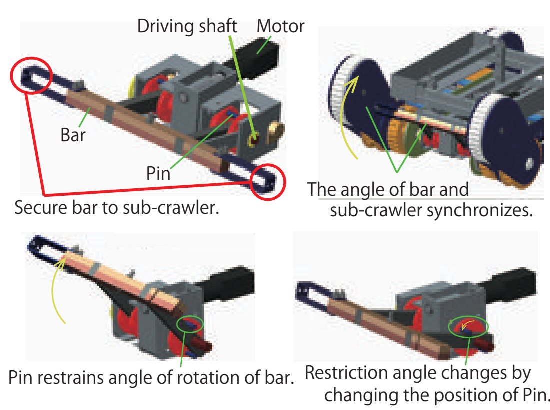

Fig. 6. Sectional View of sub-crawler

scott can invade. Scott is shown in Figure 7 a possible invasion space. Also Scott can invade the narrow-mindedness space where a human being is hard to invade and can investigate.

2) Manipulator arm : Figure 8 shows the manipulator arm that has two links is mounted on the Scott. Like robot body can not enter, it is possible to confirm the target of

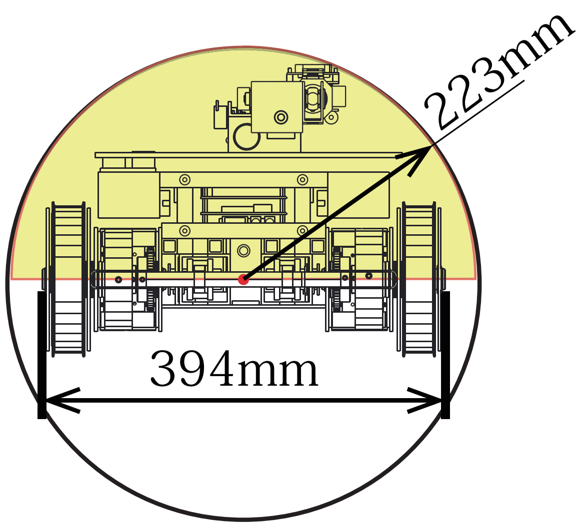

Fig. 7. Sectional View of sub-crawler

the narrow space or high position. The maximum length of manipulator arm that is stretched is about 1m. The manipulator arm has a camera, thermal sensor, Co2 sensor, LED lights and a microphone on the tip.

Fig. 8. Manipulator arm

3) Sensor for Navigation: The camera is put on front, rear, arm top, four places of the bird view of the arm. The camera has a waterproofing, and the number of the pixels is 628 $\times$ 586. The cameras are attached to four places of robot. (front, rear, tip of arm and place where operator look around the front of robot) The operator can investigate at the place that is dark when turns on the LED of the robot.

4) Sensor for Victim Identification: We show a CO2 sensor in Figure 10, the measurement range becomes 0-5000ppm. We show a temperature sensor in Figure 11, the measurement range becomes -20 degrees Celsius - 200 degrees Celsius.

We show a microphone in Figure 12, we think that it leads to victim discovery to pick up the voice of the person.

Figure 13 is a photograph when robot read QR cord. The QR code is read using a camera of the arm top.

Fig. 9. LED

Fig. 10. CO2 Sensor

Information is transmitted to an operator and uses the sensor information that I acquired for discovery of victim.

B. Software

Figure 14 shows the diagram of the system configuration. Our system uses Windows OS and ubuntu OS. Windows OS uses for information gathering and operation system. Ubuntu OS makes the environmental map using HectorSLAM.

1) Environmental map: The disaster site is often the unknown situation. The local environmental map make from the information by investigation robot is effective for a rescue operation. Therefore a lot of researcher research of SLAM(Simultaneous Localization and Mapping). Our system make the environmental map by HectorSLAM and distance datas are measured by laser range finder. Figure 15 is the map

Fig. 11. Temperature Sensor

Fig. 12. Microphone

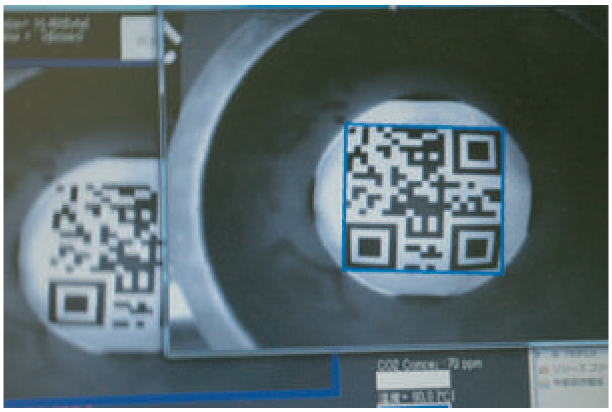

Fig. 13. Read QR cord

data which made at RoboCup Japan Open 2015. Also, our mapping system can indicate victims discovered. Figure 16 was made by the experiment in the tunnel.

C. Communication

- Our wireless LAN router supports IEEE 802.11 a .
- The channel supports 36, 40, 44, 48, 52, 56, 60 and 64.
- The band width is 6-54Mbps.

D. Human-Robot Interface

The operator of the robot uses a gamepad basically. However, we think about the burden on operator and adopt the master slave system. Gamepad and the master arm connect to operation PC. Four cameras are put on a robot. The live stream is transmitted to the operation PC. The PC for SLAM makes the environmental map in information of LRF. The operator investigates it with the help of a sent live stream and an environmental map.

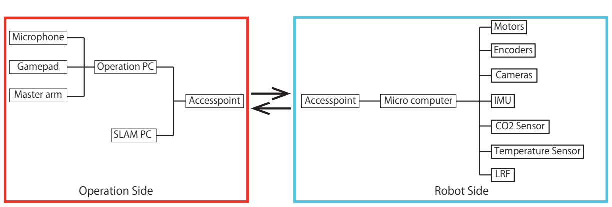

Fig. 14. system configuration

Fig. 15. SLAM

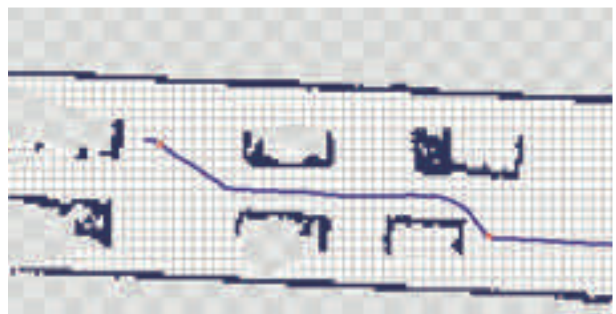

Fig. 16. Made in experiment in the tunnel

1) Master-slave system: The investigation arm is put on a robot. Investigation arm is usually controlled with a gamepad. However, the movement of the arm and the button placement of the game pad do not have linkage. Therefore the operation with the game pad burdens the operator. Accordingly, we are using the controller of the shape same as an arm shown in the following Figure 17. It is common knowledge that master-slave system has the intuitive operability, because the structure of master arm is the same structure as the slave arm (Figure 18).

2) Warning system: We use a warning system to assist the operator with route selection. It evaluates the stability of the robot on the basis of the NE stability margin. As shown in the Figure 19, the robot body posture for the pitch and roll directions and the stability will be displayed on the operation screen to determine the appropriateness of the route selection. Depending on the deterioration of the stability margin, the background color of the display is sequentially changed from blue, to yellow, and finally to red.

3) User interface: We think that the fireman operates a robot. The operation screen takes the opinion of the fireman into account. Figure 20 is the operation screen which we made. The bar expresses the motor output and the sensor information. The text expresses present status.

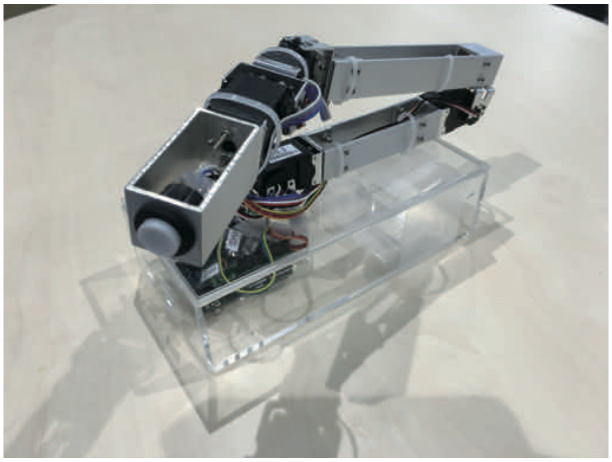

Fig. 17. Master arm

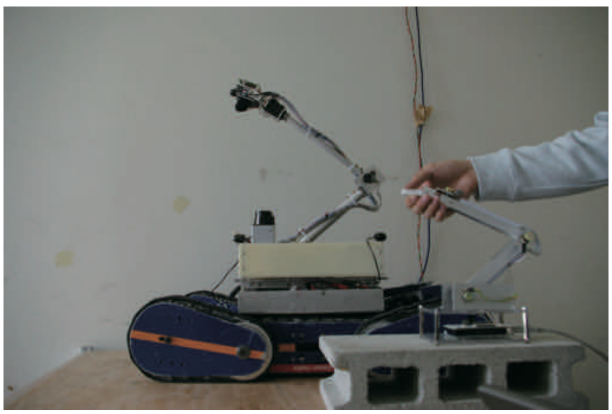

Fig. 18. Master-slave system

III. Application

A. Set-up and Break-Down

Set-Up

1) Set up PCs, game pad controller, master slave controller and wireless access points to operator station.
2) Confirm wireless access points and robot connection.
3) Our preparations are complete.

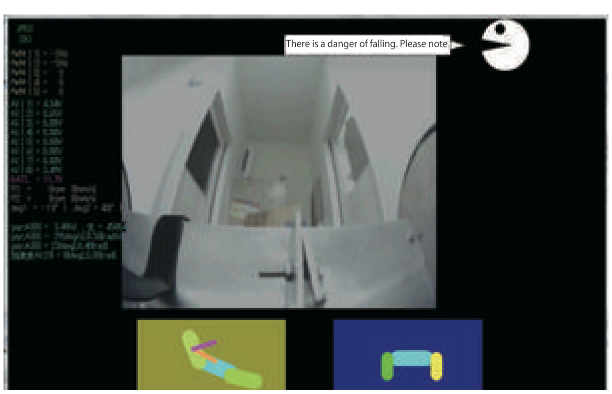

Fig. 19. Warning system

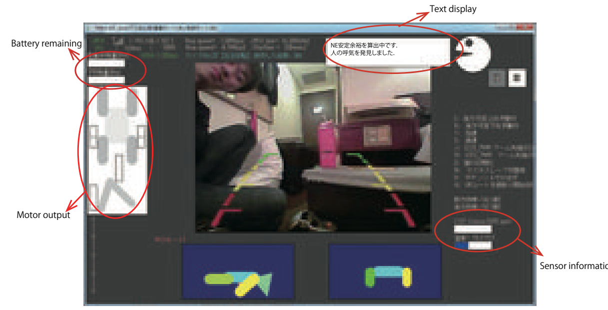

Fig. 20. User interface

Break-Down

1) Shut down all systems.
2) Remove PCs, controllers and other items.

B. Mission Strategy

We do course choice carefully. And we want to investigate more places. The investigation of a narrow space can make use of the littleness of the robot. We want to gather a lot of victim information using a sensor.

C. Experiments

We have a field of NIST of the size of Japan (Figure 21). The mobility test reaches by running the whole course of random step and closing ramp. In addition, we test it in narrow space test by going in a pipe such as Figure 22. We use a pipe wall for the test of the manipulation system. QR cord is installed in the pipe and lets you recognize it with a camera of the arm top. I aim at the acquisition of the operation of the manipulator in this way.

Fig. 21. random step

D. Application in the Field

Because size is relatively small, an investigation is also possible in narrow space. Our concept is "simple control" and "quick response to the disaster site". We performing a field experiment toward practical use with a fire department. The robot is moved in the field which is near to the disaster site. Then we can discover many problems about Mobility. We have a fireman operate the robot like Figure 23.

Fig. 22. Field of narrow speace

Fig. 23. field experiment with a fire department

Then we can hear the opinion of the user. We participated in "robot development and introduction for next-generation social infrastructure" in project of Japanese Ministry of Land, Infrastructure and Transport. Here, the ceiling collapse accident of the tunnel was assumed and investigated the tunnel of 700m. we investigated it using four robots to the tunnel inside. Flammable gas was installed in the tunnel and was able to investigate the density of gas. The making of the automatic generation report such as Figure 24 can using the data which a robot acquired.

IV. Conclusion

We research the robot which have high mobility on rough terrain, and is easy for the operator to control. We want to perform these evaluations through Robocup. Obtained the results, we want to make the disaster site making of useful robot.

Appendix A
Team members and Their Contributions

- Soichiro Suzuki — Mechanical design & Leader
- Hiroyasu Miura — SLAM algorithm
- Ayaka Watanabe — Software design
- Akira Shibata — Arm design
- Syunsuke Kodera — Mechanic
- Syuta Takkemura — Software design
- Taisei Teramoto — Mechanic
- Masayuki Okugawa — Advisor

Fig. 24. Investigation report

Appendix B
CAD Drawings

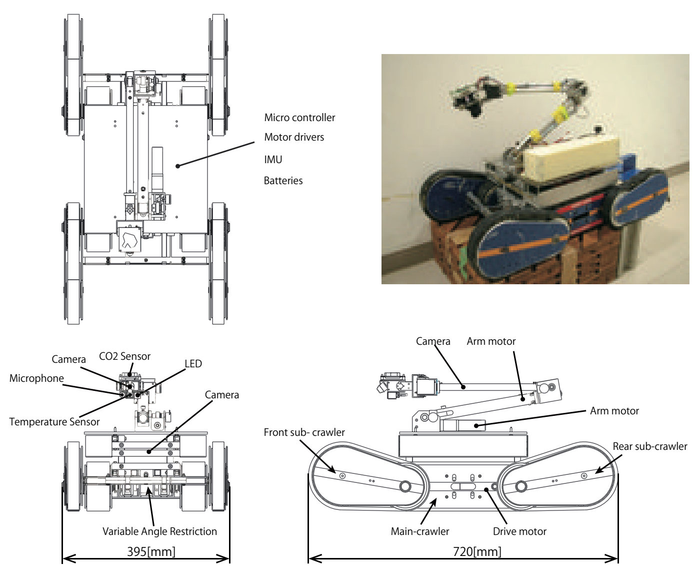

Fig. 25. CAD Drawings

TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	Scott
Locomotion	tracked
System Weight	23kg
Weight including transportation case	36kg
Transportation size	0.8 x 0.5 x 0.4 m
Typical operation size	0.7 x 0.4 x 0.2 m
Power consumption (idle/ typical/ max)	? / 60 / ? W
Battery endurance (idle/ normal/ heavy load)	120 / 90 / 60 min
Maximum speed (flat/ outdoor/ rubble pile)	0.5 / 0.2 / 0.2 m/s
Payload (typical, maximum)	?/ ? kg
Arm: maximum operation height	120 cm
Arm: payload at full extend	2.7kg
Support: 1 battery chargers total weight	2.1kg
Support: 1 battery chargers power	400W (100V AC)
Support: Charge time batteries (80%/ 100%)	40 / 60 min
Support: Additional set of batteries weight	1.2kg
Any other useful attribute	?
Cost	10000 USD

TABLE II
OPERATOR STATION

Attribute	Value
Name	ScottOp
System Weight	6kg
Weight including transportation case	8kg
Transportation size	0.5 x 0.4 x 0.28 m
Typical operation size	0.4 x 0.4 x 0.4 m
Power consumption (idle/ typical/ max)	? / ? / ? W
Battery endurance (idle/ normal/ heavy load)	6 / 4 / 3 h
Any other useful attribute	?
Cost	1500 USD

TABLE III
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Drive motors	Maxon EC-4pole 30 100 W	CHF 617.4	2
Drive gears	Planetary Gearhead GP 32 HP	CHF 211.6	2
Drive encoder	Encoder MR Type ML 500 CPT 3 Channels	CHF 100	2
Motor drivers	ESCON Module 50/5	CHF 191.4	2
DC/DC	23155	20 USD	2
Batteries	A123 26650M1 7S1P	272 USD	2
Micro controller	TPIP3	100 USD	1
WiFi Adapter	WLI-UC-AG300N	23 USD	1
IMU	UM7-LT	130 USD	1
Cameras	EC533-B	25 USD	4
Microphone	AT9942	15 USD	1
Temperature Sensor	NCM1835	100 USD	1
LRF	UST-20LX	200 USD	1
CO_2 Sensor	CO2Engine K30	50 USD	1
Battery Chargers	BC8DX	250 USD	1

TABLE IV
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	12.04	open	
ROS	indigo	BSD	
OpenCV	2.4.11	BSD	Haar: Victim detection
Zbar	0.1.0	LGPL	QR code
Hector SLAM		BSD	2D SLAM
Application for AIT pickers	2.3	closed source	Operator Station

APPENDIX C
LISTS

A. *Systems List*

B. *Hardware Components List*

C. *Software List*

ACKNOWLEDGMENT

We would like to thank Sanritz Automation Co. Ltd. for the development of the computer, "TPIP".

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