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Wireless Teaching Pendant for Mobile Welding Robot in Shipyard

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Abstract: The teach pendant is a hand-held robot control terminal that provides a convenient means to move the robot, teach locations, and run robot programs. Nowadays, almost teaching pendant is connected with a robot controller using cable. The cable connection and the size of teaching pendant are not problems because a robot controller is separated with robot. However, a large size and wired teaching pendant is not suitable for a self-deriving mobile welding robot which has a controller inside.In this paper, using a personal data assistant, the wireless teaching pendant is developed for the mobile welding robot which can weld and move autonomously in the double hull structure of the ship. We also verify the functions and performance of wireless teaching pendant from the experiments.

1. INTRODUCTION

A teach pendant(TP) is a hand-held device that controls a robot. It has basic operations that are executing robot program, setting a location of robot, emergency stopping, jogging each axis, etc. In this paper, we present a concept and implementation of the wireless teaching pendant using personal data assistant(PDA TP) for mobile welding robot.

1.1 Features of Teaching Pendant

A teaching pendant has a LCD showing information(current location of each axis, current state of the robot program, etc) and buttons for operating(Fig. 1).

Fig. 1. The teaching pendant of many types

A teaching pendant can send the commands to the controller and receive a robot status from the the controller, and show the current status of each axis, works, etc. An important role of TP is a robot program file adjustment. A robot program file is made by off-line programming(OLP). A robot program file that is called JOB file is a list of working commands of robot. Ideally, JOB file from off-line programming should have an exact information of working part. However, it is not possible to execute the robot directly using the JOB file because the working part usually has some errors. In this case, a worker correct the JOB file using TP seeing the working part for exact work. It is a necessary operation as far as having errors of working part.

1.2 Why Wireless Teaching Pendant

The TP of industrial robots size is large. Usually, the size of long side is larger than 300*mm* like Fig. 2.

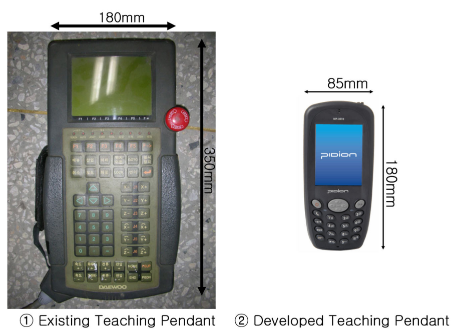

Fig. 2. Existing TP of fixed type welding robot and PDA TP

A TP is typically connected with a robot controller using cable. The cable connection and the size of TP are not problems because a robot controller is separated with robot. However, there are some problems in integrating system of robot and controller. A large size and wire connection of TP is not suitable for a mobile robot which has a controller inside. It is difficult to mount a TP because of robot size and if TP is connected with cable, a worker should follow the robot every location. To manage these drawbacks, we develop a wireless teaching pendant using personal data assistant. Table 1 shows a specification of existing TP of fixed type welding robot(Lee et al. [1998]) and developed PDA TP. From the size, weight, and wire, we can find that PDA TP is more suitable for mobile welding robot.

Table 1. Specification of fixed type welding robot TP and PDA TP

Item	Existing TP	PDA TP
Size	$180mm \times 350mm$	$85mm \times 180mm$
Weight	$1330g$	$410g$
Wire	wired	wireless
Connection to controller	RS232C	Wireless LAN(IEEE 802.3)

2. PREVIOUS WORKS

Despite importance of TP, it has received limited research in the overall field of robotics(Emma et al. [1995]). Sugita. [2004] developed teaching support devices that is composed with three wires. This device is used by worker's hand to assist for teaching. Yanagihara et al. [2001] developed teaching advisor which can show robot's working environment to worker. Recently, there are researches about wireless TP with development of wireless handheld devices. Pablo and Corke [2001] and Wu and Chen [2004] proposed a wireless TP for industrial robots using mobile phone or PDA. More recently researches are Pires and Godinho [2005] and Comau [2006]. Pires and Godinho [2005] proposed an industrial robot control method using PDA. In company, Comau [2006] developed a wireless TP for industrial robots. These researches are only for simple robot action or for the robot that has fixed base body. Differing from previous methods, in this paper, we develop a wireless TP for mobile welding robot which has a controller inside.

3. MOBILE WELDING ROBOT - 'RAIL RUNNER'

The wireless TP of this paper is developed with the controller(Lee et al. [2008]) of third version(RRX3) of self-driving welding robot - 'Rail Runner' that was proposed in Lee et al. [2007]. The 'Rail Runner' is developed by Seoul National University and Daewoo Shipbuilding & Marine Engineering(DSME).

3.1 Rail Runner

The shape of mobile welding robot, 'Rail Runner'- RRX3, is shown in Fig. 3-①. There is 6-axis welding unit in front of the robot and the body contains a mechanism for self-moving side, front, and back(Kim et al. [2008]). Fig. 3-② shows the wireless access point that built into the rear of RRX3 for connection with PDA TP(Fig. 3-③).

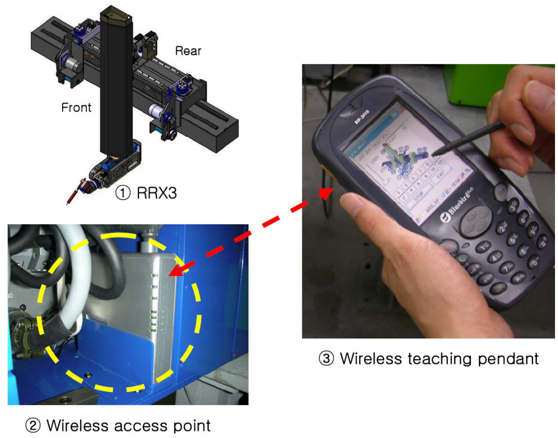

Fig. 3. RRX3, Wireless access point, and PDA TP

3.2 Wireless Access Point on Mobile Welding Robot

Fig. 4 shows the wireless access point.

Fig. 4. Wireless access point

The specification of the wireless access point is shown in Table 2(LINKSYS [07]).

Table 2. Wireless access point specifications

Item	Specification
Model Number	WRT54GC
Standards	IEEE 802.3, IEEE 802.3u, IEEE 802.11g, IEEE 802.11b
Ports	Internet: One 10/100 RJ-45 Port, LAN: Four 10/100 RJ-45 Switched Ports
Wireless Security	Wi-Fi Protected Access (WPA/WPA2 Personal), WEP, Wireless MAC Filtering
Dimensions	$98mm \times 98mm \times 25mm$
Weight	$0.141kg$
Storage Temp.	-20°C to 70°C

4. TEACHING PENDANT USING PDA

4.1 Hardware Structure of the PDA TP and the Main Controller

The hardware structure of the PDA TP and the main controller is shown in Fig. 5. As the 'Rail Runner' is a self-driving welding robot, it has controller inside. The controller is composed by wireless access point for wireless connection, CPU board for controlling the motion controller, and motion controller for controlling motors. The PDA TP is connected with the wireless access point without wire. The CPU board and the motion controller is connected with the wireless access point with LAN cable.

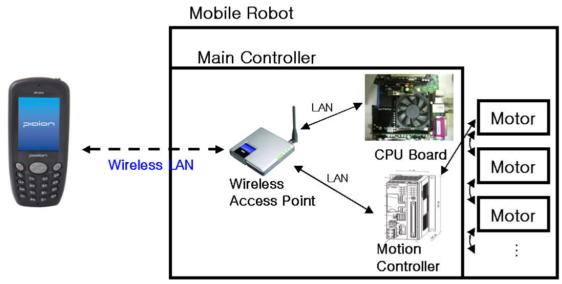

Fig. 5. Hardware structure of PDA TP, wireless access point, CPU board, and motion controller(Lee et al. [2008])

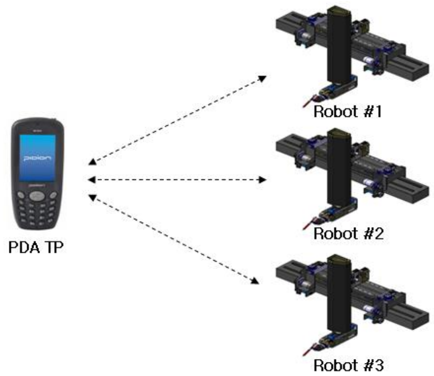

Fig. 6. Multiple connection of the PDA TP and the 'Rail Runner'

Fig. 6 shows multiple connection of one PDA TP and the several 'Rail Runner'. It is possible to control the several 'Rail Runner' using one PDA TP.

4.2 PDA Specification

Being used in hard condition of double hull structure such as high temperature and heavy fume, PDA TP should be resisted in industrial environment conditions. So, we select an industrial PDA for TP.

Table 3. PDA Specification

BIP-3010	Specification
CPU	Intel X-scale 400MHz
OS	Windows CE.NET
Memory	RAM: 64MB, ROM: 96MB
Antenna	External: CDMA, Internal: WLAN
Environment	IP54, 12 times drop 1.5m concrete
Operation Temp.	-20°C to 50°C

Table. 3 shows the specification of the BIP-3010 of the Bluebird Soft Inc(Bluebird [2007]). The notable thing is that the PDA is satisfied with IP54 condition. The IP means Ingress Protection. The first digit indicates protection for equipment. The digit 5 means that a body 1.0mm in diameter must not be able to enter. The second digit indicates the protection against water and dust. The dight 4 means that dust penetration is not prevented altogether, but dust must not enter in sufficient quantities to prevent the equipment from operating satisfactorily, or to impair safety(IP54 [2007]).

4.3 Software Structure of the PDA TP and the Controller

The software structure of the PDA TP and the controller is defined by relation of TP, main controller, and robot.

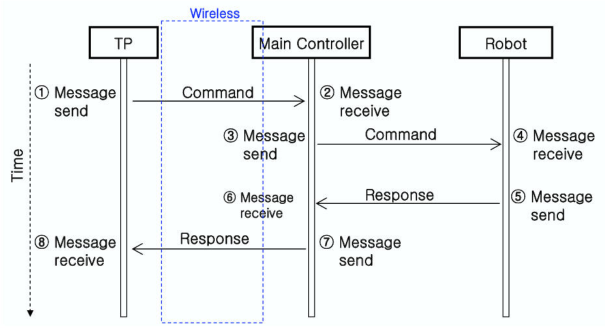

Fig. 7. Message passing within TP, main controller, and robot

Fig. 7 is a sequence diagram of relation of the TP, main controller, and robot. First, PDA TP sends a command to the main controller through wireless LAN(Fig. 7-①,②). Next, the main controller sends a command related with the message from the TP to the robot(Fig. 7-③) and the robot is moving(Fig. 7-④). Being moving, the robot sends the status of each joint to the main controller(Fig. 7-⑤,⑥). Next, the main controller sends the current status to the TP through wireless LAN(Fig. 7-⑦,⑧). The command of each step is a form of message. The main controller analyzes the message and sends proper robot motion to the robot. The structure of message are presented in next section.

4.4 Structure of the Message

The structure of the message which is used in the PDA TP and the main controller is shown in Fig. 8.

Message type	Command number	Data size	Data 1	Data 2	Data 3	···
①	②	③	④	⑤	⑥	

Fig. 8. Message structure of the TP

The message is stored in one dimensional array. The message type is stored in the space of Fig. 8-①. The message type means that it has a return value or just sending value. The command to be executed is saved in the space of Fig. 8-②. In the space of Fig. 8-③, the size of data is saved and data of each command is stored in the next space.

Return type	LOAD JOB	sizeof(job _name)	"job1.rjb"		
①	②	③	④		

Fig. 9. Example of JOB loaing message

Fig. 9 is an example of message for JOB loading command of the TP. In the space of Fig. 9-①, the 'Return type'is saved because the information of loading JOB is returned from the main controller. Next, the command of 'LOAD JOB'which means loading the JOB is saved in Fig. 9-②. The size of JOB name is saved in Fig. 9-③ and the

JOB name is saved in Fig. 9-④. When the TP sends this message to the main controller, the main controller execute loading JOB and return the result. The returned message is as same as a message of TP except type and command.

4.5 Functions of PDA TP

The PDA TP has functions related with JOB(WORK Menu), welding(WELD Menu), user(USER Menu), environment(ENV Menu), and jogging(JOG Menu). The explanation of the functions are shown in Table. 4.

Table 4. Functions of the PDA TP

Menu	Function
WORK Menu	load JOB, make new JOB, save JOB, etc.
WELD Menu	set welding condition, set ending condition, set welding sensor data, etc.
USER Menu	set home position, set software limit, set digital in/out, etc.
ENV Menu	load environment condition, set offset, set motor break, set motor gain, etc.
JOG Menu	jog each axis

The function of WORK is related with JOB which is needed for robot running. The function of WELD is for welding such as welding condition and sensing condition. The function of ENV is for environments of robot such as tuning gain and setting break. JOG function is related with jogging axis. We will give an example about loading and executing JOB which is a most important function of the robot. It is a total process of controlling robot using PDA TP.

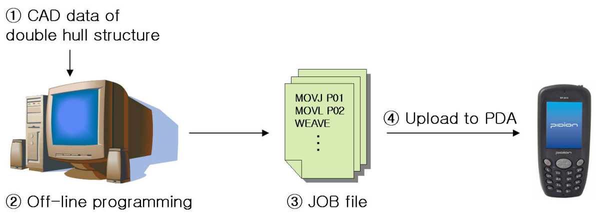

Fig. 10. Making JOB process and uploading to PDA TP

Fig. 10 shows the method of creating JOB file for robot motion. A JOB file is maid by OLP using CAD data of working space(Emma et al. [1995], Jacobsen [2005]). The JOB is stored in the developed PDA TP.

Fig. 11 is a sequence diagram of loading and executing JOB. The PDA generally has a memory for saving data. So, JOB file made by off-line programming is saved in the developed PDA TP (Fig. 11-①). The PDA TP uploads the JOB file to the hard disk of the robot main controller through wireless FTP(Fig. 11-②). Next, the TP sends uploading JOB command to the memory of the main controller(Fig. 11-④) and then the main controller sends message of JOB information to the TP(Fig. 11-⑦). When the TP sends executing JOB command to the main controller(Fig. 11-⑨), the main controller analysis each JOB line and sends motions to the robot(Fig. 11-⑪). When the main controller receives the information of the robot status(Fig. 11-⑭), it sends current status of the robot to the TP(Fig. 11-⑮) and then the TP displays current JOB line. The result of implemented PDA TP is shown in section 5.

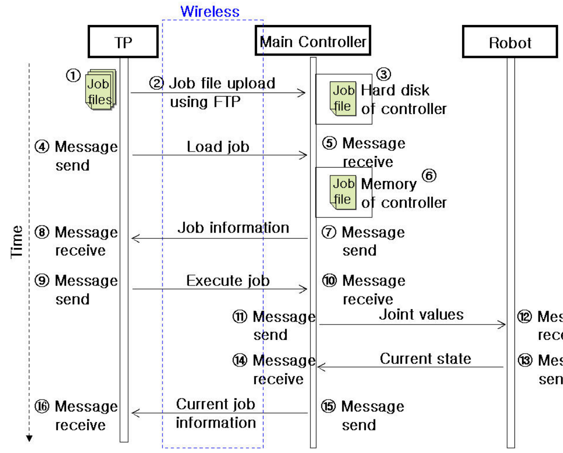

Fig. 11. Loading and executing JOB process

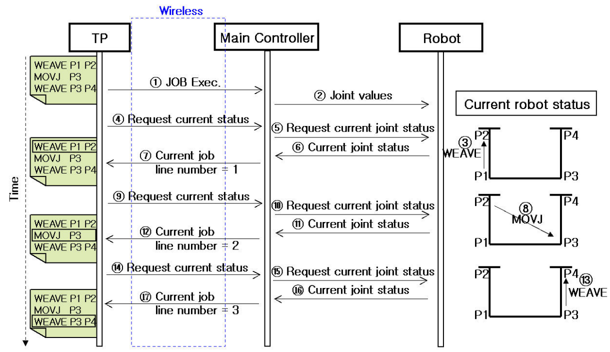

Fig. 12. Example of message passing after executing JOB

Fig. 12 presents relations of the TP, main controller, and robot after executing JOB command. This example is about JOB which has three lines WEAVE, MOVJ, and WEAVE. The WEAVE is a vertical welding process, MOVJ is a moving process. When a user execute the JOB(Fig. 12-①), the main controller send moving commands to the robot(Fig. 12-②). Then, the robot execute the first line of the JOB(Fig. 12-③). At this moment, the TP requests current status to the main controller for identifying current JOB status(Fig. 12-④). And then, the main controller request current joint status to the robot(Fig. 12-⑤) and the robot return current joints status(Fig. 12-⑥). After that, the main controller analyzes current joint status related with JOB and send current JOB line number to the TP(Fig. 12-⑦). Then, the TP highlights current line of JOB and these sequences are repeated. The WORK, WELD, USER, ENV functions have same sequences like Fig. 11, Fig. 12. The jog function is similar with this sequence except some differences.

Fig. 13 is a jog sequence diagram of connection with the TP, main controller, and robot(Fig. 13). The jog function does not have return value and should stop immediately when the jog stop button is pushed. The TP sends JOG FLAG ON message to the controller at 1/100sec interval(Fig. 13-①, ⑧). In this short time, the controller runs the motors of robot(Fig. 13-③, ④) and sets the JOG FLAG off immediately(Fig. 13-⑤, ⑥). Then, the motors go to the decelerating area(Fig. 13-⑦). In this status, if the JOG FLAG will not be on, all motors will stop. However, if the TP sends JOG FALG ON message

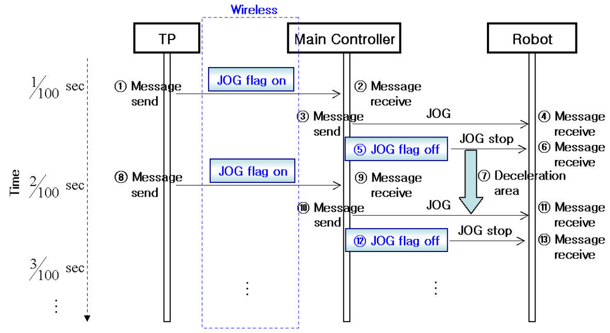

Fig. 13. Message passing of jog function

again(Fig. 13-⑧), the controller runs the motor on(Fig. 13-⑩, ⑪).

5. RESULT

Fig. 14 shows JOG motion of RRX3 using PDA TP. The robot is exactly controlled by PDA TP.

Fig. 14. Jogging test of RRX3 using PDA TP

Fig. 15 in the last page of this paper shows functions of PDA TP. Fig. 15 shows the details of WORK Menu, WELD Menu, USER Menu, ENV Menu, and JOG Menu.

The result of implemented PDA TP is shown in Fig. 16. Fig. 16 shows loading and executing JOB process of developed PDA TP. At first, the TP is connected with the robot main controller through the step of Fig. 16-① to ③. Next, a user choice LOAD menu for loading JOB. Then there is a window which can select JOB file(Fig. 16-⑥). When a user select a JOB, there is a message about loading JOB successfully(Fig. 16-⑦). After that, the TP displays current JOB information receiving from the main controller(Fig. 16-⑧). Now the robot is ready to start moving. When a user pushes the AUTO button on the EXEC mode tab Fig. 16-⑨, the robot starts moving. The TP highlights the each JOB line of current robot status.

6. IMPLEMENTATION

The PDA used in this paper has operating system which is Windows CE .NET 4.2 and we develop PDA TP program using Embedded Visual C++ 4.2 and MFC.

The basic structure of PDA TP is a form of send() and receive() function. We implement the PDA TP program using CNetInfo class. All functions, CWork, CWeld, CUser, etc, are inheritance classes of CNetInfo class(Fig. 17). CNetInfo class has sending data (m_SendData), receiving data (m_ReceiveData), sending message function (SendingMessage()), and receiving message function (ReceiveMessage()). All inheritance classes save its data to

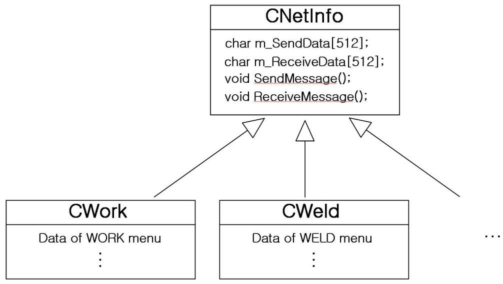

Fig. 17. Class diagram of PDA TP program

the sending data, send the data using SendingMessage() function to the main controller, and receive using ReceiveMessage() function from the main controller.

7. CONCLUSION AND FUTURE WORK

In this paper, we propose the wireless teaching pendant using PDA for mobile welding robot in the double hull structure of the ship. A wireless communication with the TP and the robot is possible because of wireless access point on the mobile robot's main controller. Also, we develop the message passing system between the PDA TP, the main controller, and the robot. We test the jogging, loading job, executing job, etc, and also verify the functions and performance of wireless teaching pendant from the experiments. The future work is controlling several robot using one PDA TP.

REFERENCES

J. H. Lee, H. S. Hwang, et al. Development of Robot Welding System for Panel Block Assemblies of Ship Hull. *Okpo Ship technologies*, Vol. 46, No. 2, 32–40, 1998.

Emma C. Morley and Chanan S. Syan. Teach pendants: how are they for you? *Industrial Robot*, Vol. 22, No. 4, 18–22, 1995.

Pablo d'Angelo and Peter Corke. A Robot Interface Using WAP Phone. *Australian Conference on Robotics and Automation*, 2001.

Shangdong Wu and Yimin Chen. Remote Robot Control Using Intelligent Hand-held Devices. *Proceedings of the Fourth International Conference on Computer and Information Technology*, 2004.

J. Norberto Pires and Tiago Godinho. Robot Control Using a Simple Wireless PDA. *http://robota.dem.uc.pt/*

Kyu-Yeul Lee, Jongwon Kim, Tae-wan Kim, Sungcheul Lee, Donghun Lee, Sol Ha, Nam-Kug Ku, Ju-hwan Cha, Soo-ho Kim. Development of a mobile welding robot for double hull structure in shipbuilding. *Robotics and Applications 2007*, pp. 29–31, 2007.

S. Sugita, T. Itaya, and Y. Takeuchi. Development of robot teaching support devices to automate deburring and finishing works in casting. *International Journal of Advanced Manufacturing Technology*, Vol. 23, pp. 183–189, 2004.

Yoshimasa Yanagihara, Sinyo Muto, and Takao Kakizaki. Evaluating User Interface of Multimodal Teaching Advisor Implemented on a Wearable Personal Computer. *Journal of Intelligent and Robotic Systems*, Vol. 31, pp. 423–438, 2001.

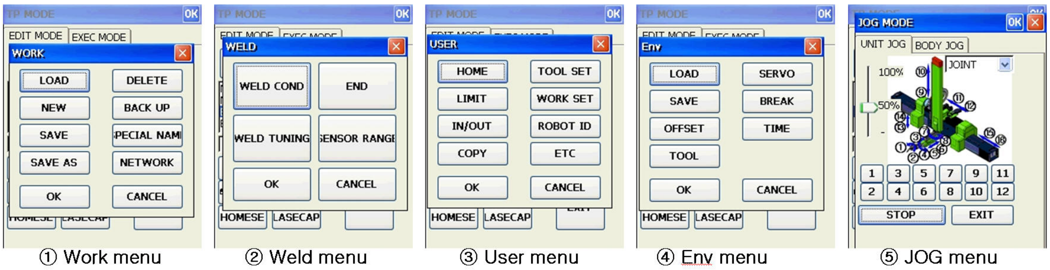

Fig. 15. Functions of the developed PDA TP

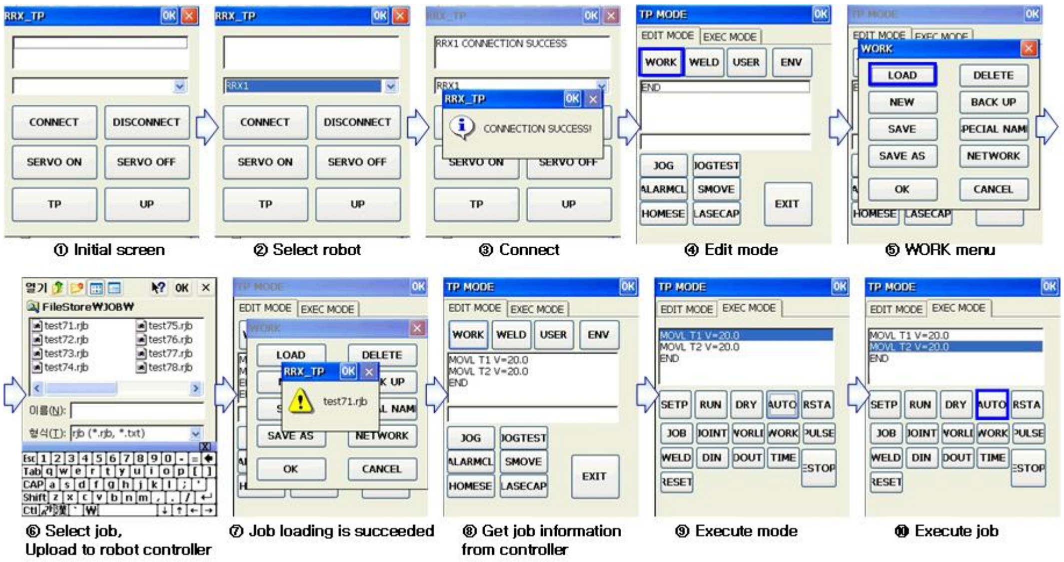

Fig. 16. Example of loading and executing JOB

Niels Jul Jacobsen. Three Generation of Robot Welding at Odense Steel Shipyard. *Proceeding of ICCAS 2005*, Pusan, Korea, pp. 289–300, 2005.

Jongwon Kim, Kyu-Yeul Lee, Tae-Wan Kim, Donghun Lee, and Sungcheul Lee. Development and Application of Autonomous Traveling Mechanism in the Double Hull Structure of the Ship. *Proceeding of IFAC 2008*, Seoul, Korea, 2008.

Kyu-Yeul Lee, Tae-Wan Kim, Jongwon Kim, Nam-Kug Ku, Hounyoung Lim, Jongjin Woo, and Sang Moo Lee. Real-time Control Architecture of Embedded Controller for Mobile Welding Robot in Shipbuilding Industry. *Proceeding of IFAC 2008*, Seoul, Korea, 2008.

http://www.comau.com/

http://en.wikipedia.org

http://www.bluebird.co.kr

http://www.linksys.com