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Design of a teaching pendant program for a mobile shipbuilding welding robot using a PDA

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ABSTRACT

Teaching pendant is a handheld device by which a human can control a robot. The main functions of a teaching pendant are moving the robot, teaching it about the locations, running robot programs, and jogging the axes. A teaching pendant is usually connected to the robot by a cable. The cable connection and the size of the teaching pendant generally do not pose a problem when the robot controller is separate from the robot. However, a large teaching pendant connected by a cable is not suitable for a self-propelled mobile robot with an internal controller. This paper describes the communication network of a personal data assistant (PDA) as a wireless teaching pendant for a mobile shipbuilding welding robot with embedded controller system that welds and moves autonomously inside the double hull structure of a ship. A double hull is a closed structure that has only a few access holes. It is very difficult and dangerous to weld components inside a double hull structure because of fumes, poisonous gas, and high temperatures. Using a wireless teaching pendant has the following advantages: (1) there are no limits to the welding activities that can take place, (2) the safety level increases because no workers are in close proximity to the robot, (3) workers are far away from the dangerous environmental conditions, (4) it is possible to reduce the weight of the cable connected to the robot, and (5) it is possible to reduce the weight of the robot because of the reduced load of the teaching pendant and the cable. We demonstrate the functionality and performance capabilities of our wireless teaching pendant through field-testing experiments.

1. Introduction

Arc welding is used extensively in shipbuilding. Most of it is performed by humans. This is challenging work because of the difficult working conditions in a shipyard due to fumes, arc sparking, electrical hazards, and high temperatures. These conditions are even more intolerable inside the double hull structure of a ship. Fig. 1 shows the double hull structure of a ship under construction.

The double hull is a closed structure with steel plates on all sides. International maritime regulations require that every oil tanker has a double hull to prevent oil spills. It is very difficult to work inside double hulls because there are only a few small access points. There is also less light, more fumes, and higher temperatures than in open structures. This has driven research into the use of robots in shipyards and led to our development of a teaching pendant (TP) for an automatic arc welding robot.

Summary of contribution

We have developed a PDA-based wireless Teaching Pendant (PDA TP) for a mobile welding robot in a double hull ship structure. We design the wireless communication network between TP and controller of the robot. We have conducted many welding tests in open and closed hull ship structures with the PDA TP to verify its robustness to the welding noise. So far we have not faced any major problem in the use of our developed device. Fig. 2 shows a welding experiment using PDA TP in a double hull structure of a ship. The PDA TP can be used for many interesting and challenging applications, e.g. for the mobile welding robot in the shipbuilding industry and for the other mobile robots in other industries, etc.

2. Background

2.1. Working space—Double hull

The required welding tasks inside a double hull structure involve U-shaped parts at the intersection of the transverse web

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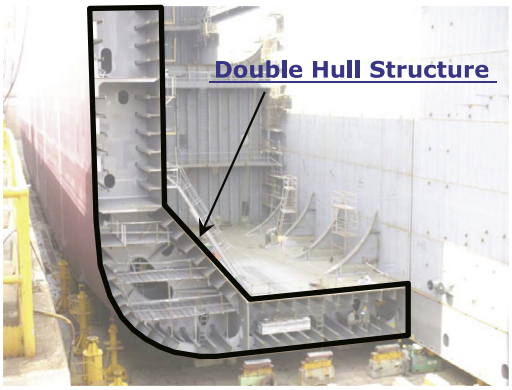

Fig. 1. Double hull structure of a ship under construction.

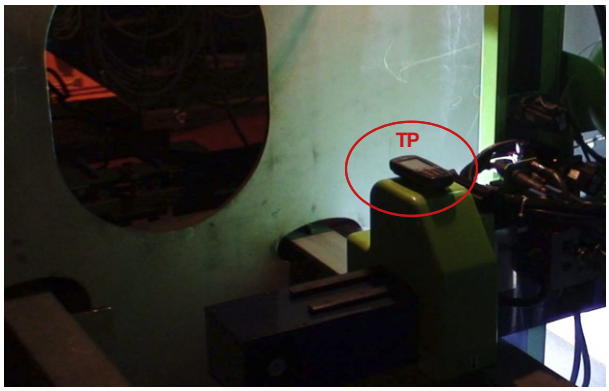

Fig. 2. Welding experiment with the developed TP in a double hull ship structure.

floor and the longitudinal stiffener. Fig. 3-① shows the double hull of a ship and Fig. 3-② shows the double hull with the upper plate removed. The U-shaped working space is shown in Fig. 3-③. The workers enter through the access manhole, (Fig. 3-④).

2.2. Shipbuilding mobile welding robot—'Rail Runner'

Because of the longitudinal stiffener, a mobile robot cannot move freely along the U-shaped welding parts. When the robot is inserted in the open structure before the upper plate is installed, it is possible to use a crane to move the robot and the U-shaped parts to other areas. Therefore, a fixed-type welding robot can

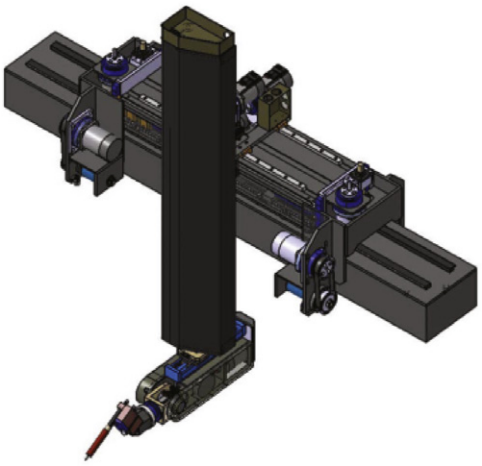

Fig. 4. Rail Runner self-propelled shipbuilding welding robot.

be used. However it is difficult to use a crane and impossible to use a fixed-type welding robot in a double hull structure [2]. The 'Rail Runner' is a self-propelled mobile welding robot designed for welding the U-shaped portions of a ship's double hull structure [1]. The Rail Runner can be inserted through the access hole, weld the U-shaped part, and move automatically from one welding area to another. The wireless TP described in this paper was developed to work with the Rail Runner controller described elsewhere [3]. The Rail Runner was developed by Seoul National University and Daewoo Shipbuilding & Marine Engineering. Its structure is shown in Fig. 4. There is six-axis welding unit on the front of the robot, and the body contains a self-propulsion mechanism for sideways, frontwards, and backwards motion [3].

2.3. Teaching pendant definition and function

A TP is a handheld device for controlling a robot. It can perform basic operations such as executing robot programs, designating robot locations, halting the robot in an emergency, and jogging each axis. In this paper, we show how a personal digital assistant (PDA) can be used as a TP for a mobile welding robot. A TP has buttons for control purposes and a liquid crystal display to show information such as the current location of each axis or the current state of the robot program (Fig. 5).

A TP can send commands to the controller, receive robot status reports from the controller, and show the current status of each

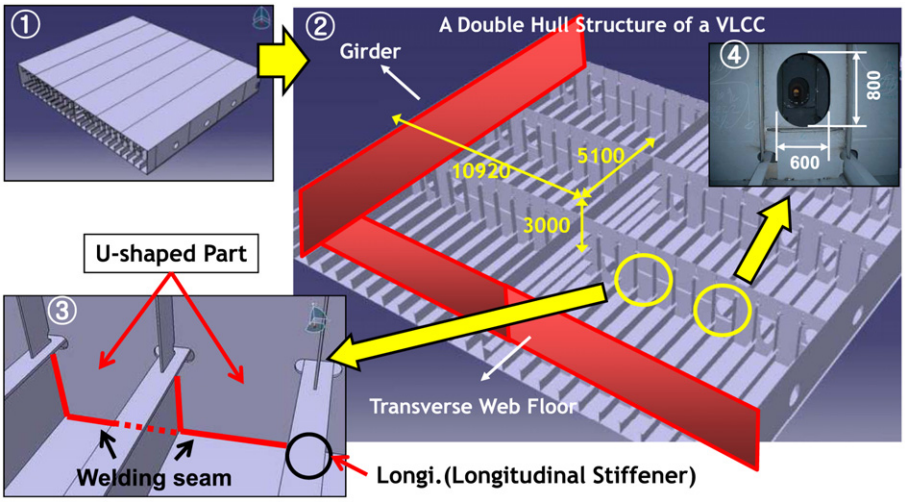

Fig. 3. Welding target in a double hull structure and access manhole [1].

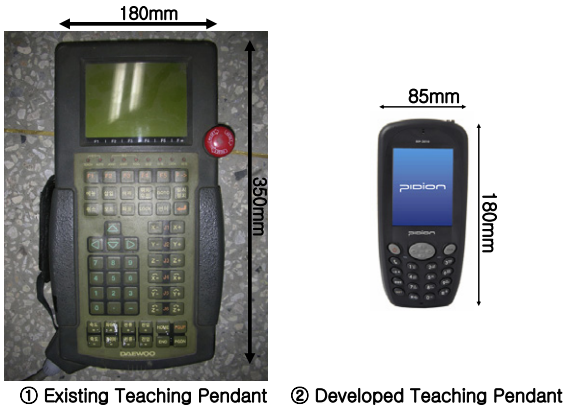

Fig. 7. Existing TP of a fixed-type welding robot used in a shipyard and the PDA TP.

Table 1
Specifications of a fixed-type welding robot TP and a PDA TP.

Item	Existing TP	PDA TP
Size (mm)	180 × 350	85 × 180
Weight (g)	1330	410
Connection	Wired	Wireless
Connection to controller	RS232C	Wireless LAN (IEEE 802.3)

Fig. 5. Teaching pendant features.

axis and program. An important role of the TP is program file adjustment. A robot program file is created by off-line programming. A robot job program file is a list of robot working commands.

Fig. 6 shows the creation of a job file for robot motion. A job file is created off-line using a computer-aided design model of the working space [4,5]. For the purposes of this paper, the job is stored in the PDA TP. We will describe the job loading process and execution method later. Ideally, the job file created off-line should contain all of the exact information about the working part. However, it is not possible to run the robot directly using the job file because the working part usually contains some errors. In this case, a worker corrects the job file using the TP after viewing the actual working part.

2.4. Selection of wireless communications for the teaching pendant

TPs of industrial robots tend to be large. If the robot has many axes or functions, the TP size could be larger still. The long side of the TP is usually greater than 300 mm, as shown in Fig. 7.

The TP is usually connected to the robot controller by a cable. The cable connection and the size of the TP generally do not create a problem because the robot controller is separate from the robot. However, in some circumstances there are problems with integrating the robot and its controller. A large TP and wire connection are not suitable for a mobile robot that has an internal controller. It is difficult to mount a large TP on the robot because of the robot size, and if the TP is connected by a cable, a worker must follow the robot around. Therefore, a large wired TP is not suitable for a self-propelled robot such as Rail Runner. To address this problem, we develop a wireless TP using a PDA.

The benefits of the wireless PDA TP are as follows: (1) the workers do not need to follow the robot, (2) the workers can be far away from the difficult environmental conditions in the working space, (3) the workers can be safe from the robot's movements, and (4) the robot is easy to handle because of the PDA's size.

Table 1 compares the specifications of an existing TP for a fixed-type welding robot used in a shipyard with those of the PDA TP. The size, weight, and absence of wired connections make the PDA TP more suitable for a mobile welding robot.

3. Related work

Despite the importance of the TP in the control of robots, it has received limited research attention [4]. Sugita et al. [6] developed teaching support devices composed of three wires worn on a worker's hand to assist in teaching. Yanagihara et al. [7] developed a teaching advisor that could show the robot's working environment to a worker. These teaching advisors were connected to the robots by wire. Strictly speaking, these efforts are more closely related to the teaching advisor of a robot than to the TP. They do show, however, that the TP must provide teaching advisor functions such as teaching the motion and controlling the robot. Therefore, the TP we developed has many functions to teach the robot different motions.

There has been some research into wireless TP related to the development of wireless handheld devices. d'Angelo and Corke [8] and Wu and Chen [9] proposed a wireless TP for industrial robots

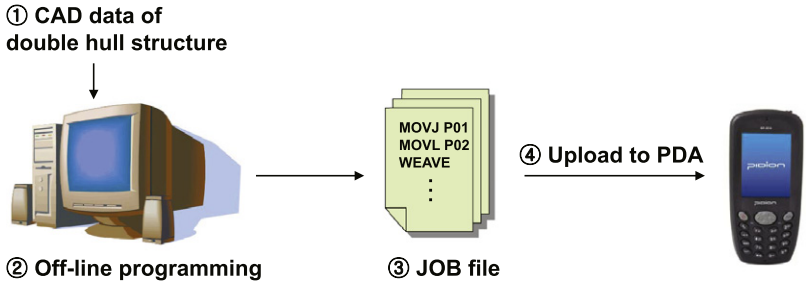

Fig. 6. Creating a job process and uploading it to the PDA TP.