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Rapid Adaptive Programming using Image Data (RAPID)

Alexander D. Nicholson
alexn@uow.edu.au

John Norrish
University of Wollongong, johnn@uow.edu.au

Paul Di Pietro

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RAPID ADAPTIVE PROGRAMMING USING IMAGE DATA (RAPID)

Nicholson A, Norrish J and Di Pietro P

ABSTRACT

In many welding applications, programming time has been the biggest obstacle for the widespread acceptance of robots, impeding the advancement of this technology and limiting it to medium or large batch applications. In particular, for repair of worn components where the damage is irregular, reprogramming by skilled personnel is required at added cost and time. This paper outlines a novel offline programming technique which allows robot programming to be automated and completed in a few seconds. This technique is applicable to a wide range of industrial wear applications.

KEYWORDS

Robotics, Offline Programming, Welding, Weld Repair

AUTHOR DETAILS

A. Nicholson, Postgraduate Student, Faculty of Engineering, University of Wollongong, NSW, Australia.
Prof. J. Norrish, Professor of Materials Welding & Joining, University of Wollongong, NSW, Australia.
Dr. P. Di Pietro, Manager Engineering Development Workshop, ANSTO Engineering Services, ANSTO, NSW, Australia.

1. INTRODUCTION

It has been estimated that conventional robot programming requires around 1 hour of programming time for every minute of welding [1]. This is justified if many identical components can subsequently be fabricated with the same program. In weld reclamation and repair situations it is often necessary to use high alloy consumables and high preheat temperatures which pose many occupational health problems for manual welders. Robotic welding offers a means to remove the welder from the hazardous environment and may also have benefits in terms of productivity and consistency. However in most industrial wear situations each component, wear pattern, and wear location is different. Dewort [2] overcame this problem by machining sets of worn components to a standard profile prior to robotic welding. Without this preparatory step repeated reprogramming would normally be required with conventional programming and this would clearly be impractical. The challenge is therefore to develop a rapid programming approach for irregular worn components. This has be achieved using a combination of tactile and video sensing combined with innovative offline programming software. The technique and the result of initial trials are described below.

2. DEVELOPMENT

The target application for this work was the repair of cavitation damage on Hydro turbine runners and was sponsored by the Power Generation research activity of the CRC for welded structures. In order to simulate this requirement a full size mock up of a segment of a turbine runner was fabricated. The following robot welding package was set up:

- ABB IRB1400 6-axis articulated robotic arm
- ABB S4C robot controller
- Fronius TransPulsSynergic 4000 multi-process power supply
- Fronius Robacta 500 push-pull torch
- Fronius VR 4000 wire feed unit

The offline programming interface was a personal computer with Intel Pentium processor equipped with the following.

- Windows XP, Ethernet adapter, serial port
- Welding data acquisition and supervisory control system
- AVT Marlin F-046C colour CCD camera

Although several cavitation resistant alloys were evaluated all of the weld programming trials were undertaken with Gas Metal Arc Welding (GMAW) with Argon 16%CO^2 2.7%O^2 shielding gas and 0.9mm 70S-4 solid wire.

The approach which was ultimately developed relies on the use of a purpose designed integrated PC management and control system for the robotic welding cell [3]. The software suite which was developed forms a communication interface between the vision system the proprietary robot programming and welding system software. It performs the following functions:

- User interface to set welding parameters and initiate programming
- Weld bead geometry calculation from chosen welding parameters
- Damaged area identification and capture
- Weld path calculation
- Path download to robot programmer

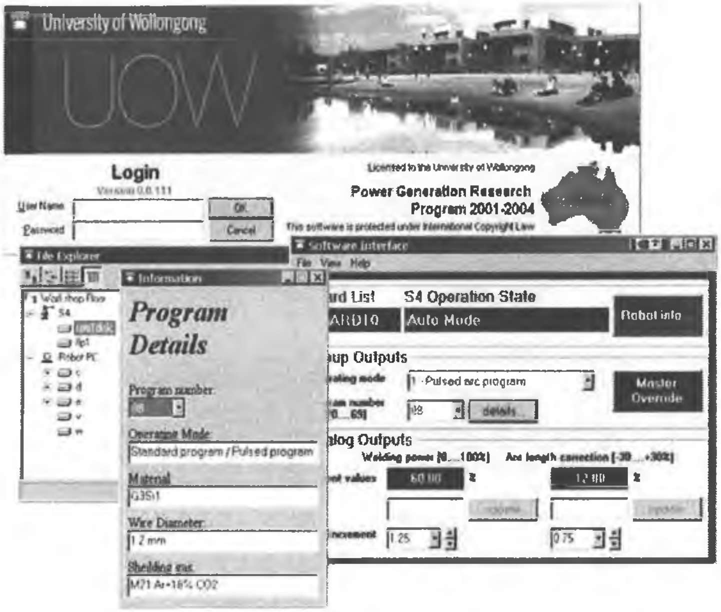
The novel aspect of the system includes the use of a vision system combined with touch sensing to define the area to be repaired.

3. SYSTEM OPERATION

The operation of the system is best illustrated by a description of the typical sensing and welding cycle as follows:

Step 1. Initiate program; software interface on the PC.

The initial software interface allows communication with the various packages which control the robot and welding system. It also allows the 'file management' of the system. A series of the initial user interface screens are shown in figure 1.



Program number: 08

Operation Mode: Standard program / Pulsed program

Material: G3Si1

Wire Diameter: 1.2 mm

Shielding gas: M21 Ar+18% CO2

S4 Operation State: Auto Mode

Operating mode: 1 - Pulsed arc program

Program number [0...69]: 08

Welding power [0...100%]: 60.00 %

Arc length correction [-30...+30%]: 12.00 %

Increment: 1.25 / 0.75

Figure 1. Software interface for robot welding cell equipment [3]

The software includes a facility for calculating the weld cross section based on the welding parameters entered by the user. This information is later use to automatically determine the spacing of the individual weld runs.

Step 2. Roughly position the robot and camera.

Once the system is set up the robot is manually positioned at a point which enables the arm mounted video camera to capture an image which includes the damaged area. In practice this position is relatively uncritical and for the current application it would normally be some 350mm away from the vertical face of the runner. The orientation of the robot and camera is shown in figure 2.

Step 3. Capture image of damaged area

With the camera in position the software is instructed to capture an image and transfer this to a window on the PC monitor. At the same time the robot coordinates are read from the robot controller and recorded.

Step 4. Manually select damage area

Using the mouse or similar pointing device the 2D repair envelope is defined. To speed up this operation a set of sophisticated algorithms are used to allow the user to define the enclosed area by selecting a few points around the periphery of the damaged area. The software automatically outlines the area rejecting any obviously erroneous points.

Figure 2. Rough positioning of robot

The defined area is then 'sliced' by the software which calculates weld paths based on weld volume data calculations. When complete the user can check the planned path before it is translated to a robot program and downloaded to the robot controller. The initial image from a simulated wear area is shown in figure 3 and the weld paths determined by the software are shown in figure 4

Figure 3. Image transferred to PC

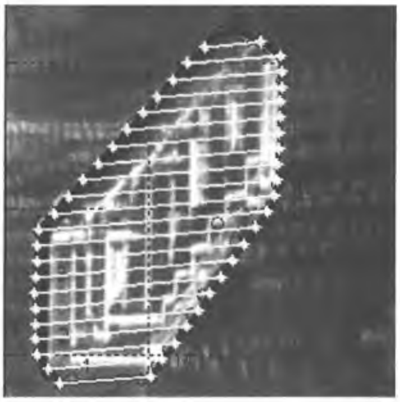


Figure 4. Automatic weld path generation

Step 5 Initiate touch sensing routine

Although the 2D (X/Y positions) profile is now defined it is necessary to determine the 'Z' position which depends on the profile of workpiece. A touch sensing routine is used to determine this 3rd dimension. The system utilises the proprietary voltage sensing facility integrated into the power source/robot package. The robot automatically advances towards the workpiece at a slow speed. When the welding wire or a special sensing tip contacts the work an impressed voltage signal falls to zero, the robot motion is stopped and the coordinates are recorded. See figure 5.

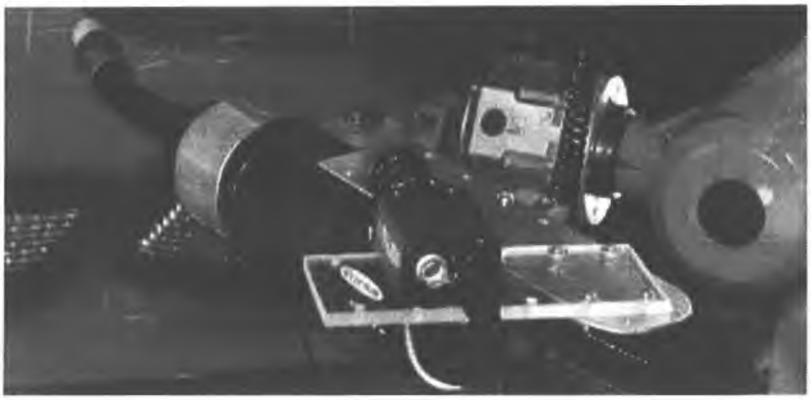


Figure 5. Touch sensing to determine workpiece profile

Step 6 Execute Welding Routine

The system is now fully programmed, the welding routine is executed and the robot automatically deposits the weld metal according to the derived program. Several stages in a build up process are shown in figure 6

Figure 6. Deposit weld metal

4. DISCUSSION

The foregoing description indicates the many stages required but in fact whilst the software is quite complex the whole process is very rapid and simple to operate. The intuitive graphical user interface is used to allow inexperienced operators to quickly learn the technique. In contrast to normal programming the complete task of teaching the robot is completed in around 30 seconds. After learning the system subsequent repairs such as in the example illustrated in figure 6 above can be completed in the same order of time as it takes to weld. Manual intervention is required to initially position the robot and to select the wear area; the remaining operations are automatic. The manual selection of the worn area was a deliberate strategy: Although vision systems could be used to automatically capture areas of damage previous experience has shown that for successful operation very carefully controlled lighting is required and errors can arise due to the poor contrast between the wear area and its immediate surroundings. The assisted manual definition of the wear pattern is very rapid and introduces a secure means of error checking; both via the software and by the human operator.

In the case of non-uniform damage (where the depth of the worn area varies), there are several options; the simplest approach is to manually assess the wear depth during initial damage assessment using a simple depth gauge. The wear area may then be built up by defining several layers on the image corresponding to the average weld layer thickness. Alternatively sophisticated laser profilometry or more extensive touch sensing can be performed. Laser profilometry is feasible and very accurate [4] but the equipment is costly and easily damaged. Extensive touch sensing to scan the surface was attempted during the course of the present work [4] and although it was capable of providing a profile map of the surface the resolution depended on the number of touch points. To achieve a detailed surface contour using touch sensing was found to be excessively time consuming.

The system was designed for in-situ repair of hydro turbine runners but could be applied to any situation where unpredictable wear patterns present themselves for weld build up and repair. Applications in power generation, mining and mineral processing are anticipated.
The software structure is applicable to many combinations of robot and welding systems. To configure the system for other robots the appropriate communication protocols (TCP/IP and RS232) and I/O connections would need to be established and a native language interpreter for the chosen robot would need to be installed.

5. CONCLUSIONS AND FURTHER WORK

For wear replacement where the damaged area is unpredictable in both location and extent, conventional programming is often not feasible due to repeated reprogramming of the robot. A rapid offline programming technique has been developed and tested using image data from a standard digital camera. Once the damaged area has been identified, (in conjunction with the software interface discussed further in [3]), welding can usually begin in less than a minute. This gives the system a substantial advantage over conventional methods.

There are several options for enhancing the system; including automatic depth sensing, online video capture, 3D (curved surface) calibration, automated surface grinding, and dedicated programmable mechanism design.

The system is functioning and has been demonstrated to the CRC-WS Power Generation Group which sponsored the work. Further investigations are underway as part of a PhD program at the University of Wollongong (UOW).

6. ACKNOWLEDGEMENTS

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