Use of Voice Recognition for Control of a Robotic Welding Workcell

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ABSTRACT: This paper describes work underway to evaluate the effectiveness of voice recognition systems as an element in the control of a robotic welding workcell. Factors being considered for control include program editor access security, preoperation checklist requirements, welding process variable control, and robot manipulator motion overrides. In the latter two categories, manual vocal control is being compared against manual tactile control and fully automatic control in terms of speed of response, accuracy, stability, reliability, and safety.

Introduction

Voice recognition technology is now recognized as a potential means for easing the workload of operators of complex systems [1]. Numerous applications have already been implemented, are in various stages of development, or are under consideration [2]-[5]. These include data entry, control of aircraft systems, and voice identification and verification for security purposes.

Voice control has also been proposed for use aboard the space station [6]-[8]. One prime area for application would be control of some functions of robots used for intravehicular inspection, assembly, repair, satellite retrieval, and satellite maintenance when a crewmember is serving in a supervisory capacity or the system is operating in a teleoperation mode. Voice control of sensors and process variables would free the crewmember’s hands for other tasks, such as direct control or override of the manipulator motion. Similarly, the workload associated with control of many onboard experiments could be eased through the use of this technology.

This paper describes the application of voice recognition for control of a robotic welding workcell. This is a complex system involving inputs from multiple sensors and control of a wide variety of robot manipulator motions and process variables. While many functions are automated, a human operator serves in a supervisory capacity, ready to override functions when necessary. In the present investigation, a commercially available voice recognition system is being integrated with a robotic welding workcell at NASA Marshall Space Flight Center, which is used as a test bed for evaluation and development of advanced technologies for use in fabrication of the Space Shuttle Main Engine. In the system under development, some functions do not yet have automatic closed-loop control, thus requiring continuous monitoring and real-time adjustment by the human operator. Presently, these overrides are input to the system through tactile commands (i.e., pushing buttons, turning knobs for potentiometers, or adjusting mechanical devices). Since the operator monitors the process primarily visually, he must either look away from the process to find the proper button or knob or rely on “muscular memory” much as a touch-typist does. In the first case, the time of response to a deviant condition may be excessive. In the second case, there is an increased probability of a secondary error being introduced by the operator.

A voice recognition system could reduce the response time required from the operator. The probability of pushing the wrong button should similarly be reduced. Also, operator fatigue should be minimized.

Since the operator can continuously monitor the process during override input, the effect of the change can be observed more quickly. Thus, if the desired value is exceeded and reverse correction is required, it should be accomplished more quickly, allowing less overshoot. This reduction in oscillation about the desired value makes the system more stable.

Another factor that can be improved is operator safety. In a safety-critical situation, the robot’s operation can be halted immediately by use of the “emergency stop,” or E-stop, mode, which is initiated, conventionally, by depressing a large button. If an operator inadvertently finds himself in a hazardous situation, it may be necessary for him to initiate the E-stop sequence. Should the operator not be within reach of the button, however, he may be unable to take the necessary action, and, as a result, could suffer serious injury. Having the capability of stopping the robot by issuing a voice command could significantly improve the operator’s safety by enabling him to stop the robot even when not within reach of the E-stop button. Manual corrections are occasionally required to adjust the location at which the weld filler wire enters the weld pool. Proper entry location is absolutely critical to sound weld quality. Adjustments are made either by manually adjusting mechanisms that hold the wirefeed guide tube or by issuing tactile commands to a servomechanism. Use of a voice recognition system could eliminate the need for the operator to place his hand within the working envelope of the robot end effector or, if servomechanisms are employed, could improve speed of response and stability.

Another aspect of robot operation in an industrial environment is that a security program editing capability of the system. Under no circumstances should any unauthorized person be able to enter this programming mode and alter the robot’s program. A voice recognition system can provide the necessary security by allowing access only for individuals who are authorized and whose voices can be identified by the system.

Background

Robotic welding is under development by NASA and Rocketdyne for the automation of welds on the Space Shuttle Main Engine that are presently made manually. The programmability of a robot can reduce the percentage of welding defects through a combination of consistency and repeatability unattainable by its human counterparts. To do this, the robot is programmed to a nominal weld path and level of weld process parameters (i.e., current, travel speed, voltage, wire addition rate). Some adjustment of these values is often necessary due to conditions changing during the weld. A human making a manual weld accomplishes this adjustment
readily, while a robot must rely on the limited talents of sensors and the ability of the operator to override functions when necessary.

**System Integration**

The basic elements of the workcell system are shown diagrammatically in the illustration. The ultimate goal of the system development work in progress is to generate robot manipulator programs and weld process programs offline, download them to the workcell supervisory computer, then use sensor subsystems to make closed-loop corrections to the robot path and process variables. Offline programming is being done with an Intergraph modified VAX 780/785-205 computer system with Interact color graphics workstations. Deviations between the programmed robot path and the actual required path are observed and corrected by a sophisticated vision-based sensor developed for this application by Ohio State University. This sensor system is also designed to permit measurement of the molten weld pool surface dimensions and correct welding current level to maintain the weld pool dimensions within desired limits. Presently, a number of functions are still controlled manually, and manual override capability is required for all functions. As stated in the Introduction, use of voice recognition may improve the accuracy and speed of response of these manual overrides. To explore this technology, a Votan VRT 6050 stand-alone voice recognition terminal has been integrated into the workcell. This system provides continuous speech recognition of up to 10 sets of words with 75–150 words per set.

The integration of the voice recognition system is broken into analog and discrete signals for control. The voice recognition system connects to the control computer through a standard RS232-C communications link.

**Discrete Control Signals**

In this project, most of the control circuitry is based on discrete digital signals. This is due to the on/off state nature of the circuits to be controlled in the robot controller. The circuits of the system to be controlled by the voice recognition control computer (VRCC) by discrete signals are the emergency stop circuit and the positive jog and negative jog circuits for motion control.

Since the safety of the operator is paramount in any automated workcell, the voice recognition system should be incorporated as
a safety feature. To accomplish this, the VRCC has been interfaced into the workcell emergency stop circuit. The emergency stop circuit in the robotic workcell will shut down the welding process and the mechanical motion of the manipulators. Through the use of a digital signal from the VRCC, a relay is energized that interrupts the necessary circuitry to the welding power supply and robot controller. With the use of the voice recognition system as a safety control for this workcell, we have added a third level of redundancy into the emergency stopping ability of the operator (in addition to the present emergency stop buttons).

Manipulator motions are controlled through an axis select button in conjunction with a positive or negative jog button that is depressed by the operator. Once the operator has selected an axis, he depresses one of the jog buttons for the desired travel distance. This function was selected to be controlled by the VRCC because of its utilization during automatic operation of the manipulator to correct trajectory errors. The circuitry necessary to control this operation draws the signal to ground through the activation of relays for the positive or negative jog motion. Because motion is achieved only as long as these signals are active low, they can be controlled by discrete digital signals from the VRCC.

Analog Control Signals

There are many variables that affect the quality of weld during the welding process, but the welding current has the greatest effect over a small range of values. It was for this reason, that the welding current was chosen to be controlled by the voice recognition system. The welding power supply controls the current level through a voltage circuit that uses a range of 0–10 V DC. These voltage values are converted to current levels from 0 to 300 A for welding. A digital-to-analog converter is used in conjunction with a multiplexing circuit. The converter allows the VRCC to control a voltage level that is used by the welding power supply to achieve the proper welding current. The multiplexing circuit is necessary to allow the weld power supply to be controlled by the other subcontroller used in the workcell.

Experimental Investigation

The accuracy and speed of response of corrections to robot manipulator motion and welding process variables made with the VRCC are being compared with those made with the original control system. Step input errors to robot motion and welding current are introduced randomly into the robot program. By graphically recording relevant system output signals, the time required for the operator to detect the change and initiate corrective action may be measured. Response accuracy and stability may also be gaged through similar analysis of the relevant recorded system output signals.

Conclusions

Future work will investigate voice control of welding filler wirefeed speed and location of wire entry into the weld pool. Also to be investigated is voice control of welding arc voltage override. Later, restriction of access to the robot program editor by voice recognition may be implemented.

The use of voice recognition technology for manual supervisory control of industrial robot systems is very promising. This technology has application for aerospace welding due to the need to have constant human supervision over a multitude of process parameters in real time. Future development of this technology will permit rapid expansion of its application to both robotic and nonrobotic processes.

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References


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