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THE NIST AUTOMATED ARC WELDING TESTBED

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ABSTRACT

The Automated Welding Manufacturing System (AWMS) is a research and development testbed for automated gas metal arc welding technology. Its activities are aimed at developing and validating standards that will contribute to increased use of automated welding technology by manufacturers. The National Institute of Standards and Technology (NIST) plans to work with technology suppliers and manufacturing users to test systems in the AWMS. Our experiments and control system designs will test the feasibility of interface standards and intelligent control technology to increase productivity, improve quality, and reduce the cost of system integration. Further, we will explore integration techniques that make multi-vendor system solutions more effective and easier to build, program, and operate.

Keywords: data acquisition, gas metal arc welding, open architecture, robotic arc welding standards, welding automation, welding sensors.

INTRODUCTION

A major NIST mission is to promote economic growth by working with industry to develop and apply technology, measurements, and standards. The Intelligent Systems Division (ISD) is part of NIST's Manufacturing Engineering Laboratory. ISD's goals are to foster the development and implementation of advanced manufacturing systems, processes, and equipment and to anticipate and address the needs of U.S. industry for the next generation of measurements and standards.

ISD began an effort to investigate technology in automated arc welding in 1995. ISD worked with NIST's Materials Reliability Division (MRD), a group that has experience in welding process research, to determine the initial approach of the project. The focus of the project is the Automated Welding Manufacturing System (AWMS), a testbed for automated welding research.

This document describes the current testbed hardware and the initial design for the control system and off-line planning systems. The testbed, shown in Figure 1, includes a robot, arc welding power source, gun and wire feed, control computers and sensors, and robot simulation software. We emphasize modular software and hardware design to investigate opportunities for standards and to allow insertion of components and algorithms developed by others.

AWMS GOALS

The three major goals of the AWMS testbed are to:

- validate and test standards
- incorporate new hardware and software components developed by others to investigate open-architecture concepts
- develop advanced welding technology.

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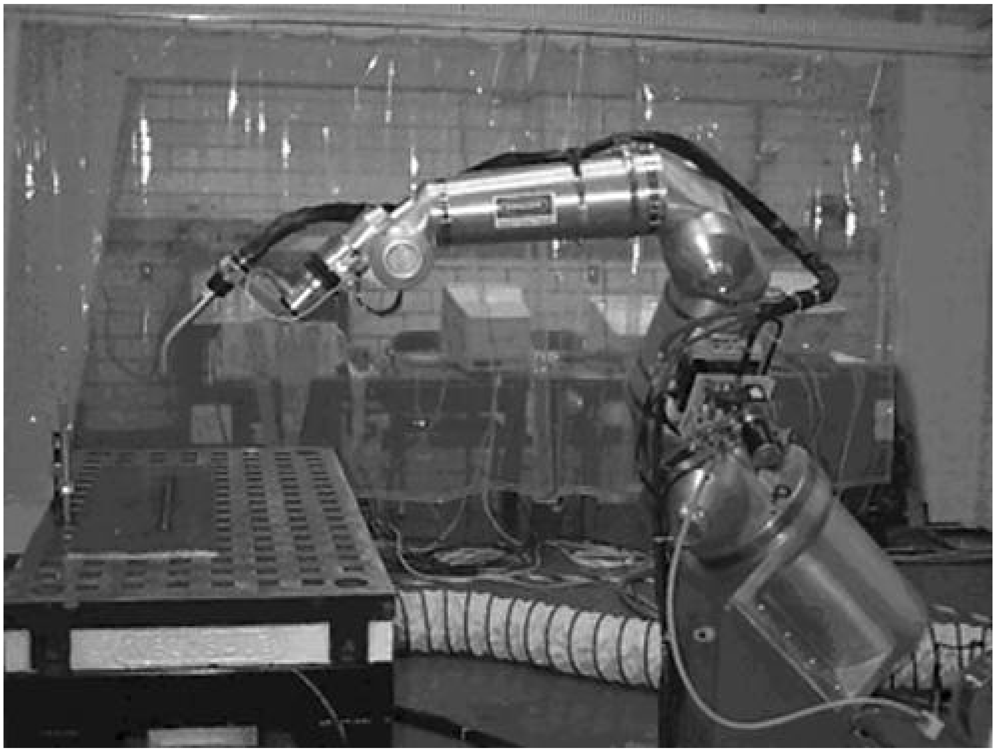

Figure 1. The robot arm of the AWMS testbed.

The scope of the standards work includes: 1) hardware and software interfaces for shop-floor computerized welding equipment, and 2) data formats for exchange among Computer Aided Design Systems (CAD), welding procedure and knowledge bases, and off-line programming systems. The goals are pursued using experiments in integration of components such as robots, power sources, weld process sensors, and robot proximity and position sensors. Emphasis of the experiments is on system welding capabilities and the ease with which products from different vendors can be integrated into the testbed. The technology subsystems will primarily be imported from commercial companies and research organizations. The AWMS project continues ISD's efforts in open-architecture methods with focus on real-time control technology. Possible testbed activities may include welding off-line planning and cell programming.

Standards cannot be validated and tested if there is an insufficient host of technology subsystems to integrate. To accomplish our mission, we will work closely with commercial companies who supply technology and who buy welding systems. We will also leverage new technologies at the university and government laboratory level and are maintaining close relations with welding standards organizations.

AWMS integration experiments will test the feasibility of:

- standards for interfaces between components that free integrators from product-by-product interface engineering. Component developers and potential developers would know that conforming to the standard would ensure compatibility of their products with other components. For the relatively small welding technology industry this ease of integration is essential to encourage companies to develop new products.
- open architecture interface standards that make it possible to access and store real-time weld process data. The data would be used in developing process models and in monitoring and controlling quality.

AWMS APPROACH

The AWMS project emphasizes experiments in the testbed. ISD is maintaining testbed hardware and software and incorporating state-of-the-art products and evolving research results. AWMS experiments address welding techniques that apply to commercial manufacturing processes. The testbed can be used to test pre-commercial technology, to anticipate the near-future needs for standards that arise from new technology development.

We are studying architectural designs and data formats developed by others, and will do validation testing of them where appropriate. Where possible, we plan to study system-level configurations and tools being developed by CYBO (Ref. 13), AWI (WeldExcel), PAWS, and Sandia National Labs (SmartWeld) (Ref. 8), to find commonality in ways to make components from each usable in other systems, or to make outputs of one system compatible with another. AWMS can be used to test and validate data formats such as those being developed by American Welding Society A9 Committee, CYBO (Ref.13) and NIDDESC (Ref.10).

AWMS control system technology emphasizes open-architecture of potentially distributed systems. The extent of distribution can range from using different computers on a local network for a cell's sensor, motion control, and power source control, to using the Internet to allow users to remotely program, control, and monitor a welding cell. The open-architecture approach uses standard interfaces that allow interoperability of products from different vendors.

Possible standards issues within the scope of the testbed include realtime hardware interfaces to robots and power sources, interfaces to sensors, open-architecture controller software application programming interfaces (api's), data formats for weld geometry and weld parameters, welding program data including motion and weld parameters. We will address these issues in cooperation with industry research partners and AWS and Robotic Industries Association standards committees. AWMS government-industry research activities will identify standards needs for the near future and demonstrate new intelligent control systems for the arc welding industry. Current manufacturing application areas being considered include, but are not limited to, shipbuilding, automotive and heavy equipment manufacturing, and the building construction industry.

TESTBED ARCHITECTURE

Figure 2 shows the major components of the AWMS testbed control structure. This is a logical architecture -- components are processes that may run on different configurations of computers. The detailed architecture may change as we experiment with configurations or implement commercial product interfaces.

The CAD-based off-line programming system will integrate commercially available computerized components for weld design and planning, and for motion planning with automation systems. An off-the-shelf CAD system will be used to create part, assembly and weld designs. This design data will then be extracted from the CAD system and passed to an off-line planning system which will merge CAD data with existing welding knowledge bases. This merged data will be input to a commercial off-line programming package where it will be integrated with motion planning, producing a welding program specific to the AWMS testbed hardware including robot/torch, speed, orientation, and sensor-guided actions. The program generated by the AWMS OLP system will then be interpreted by the AWMS Cell controller. Ideally, predictive process models could be modified to accept this standard format to verify welding plans.

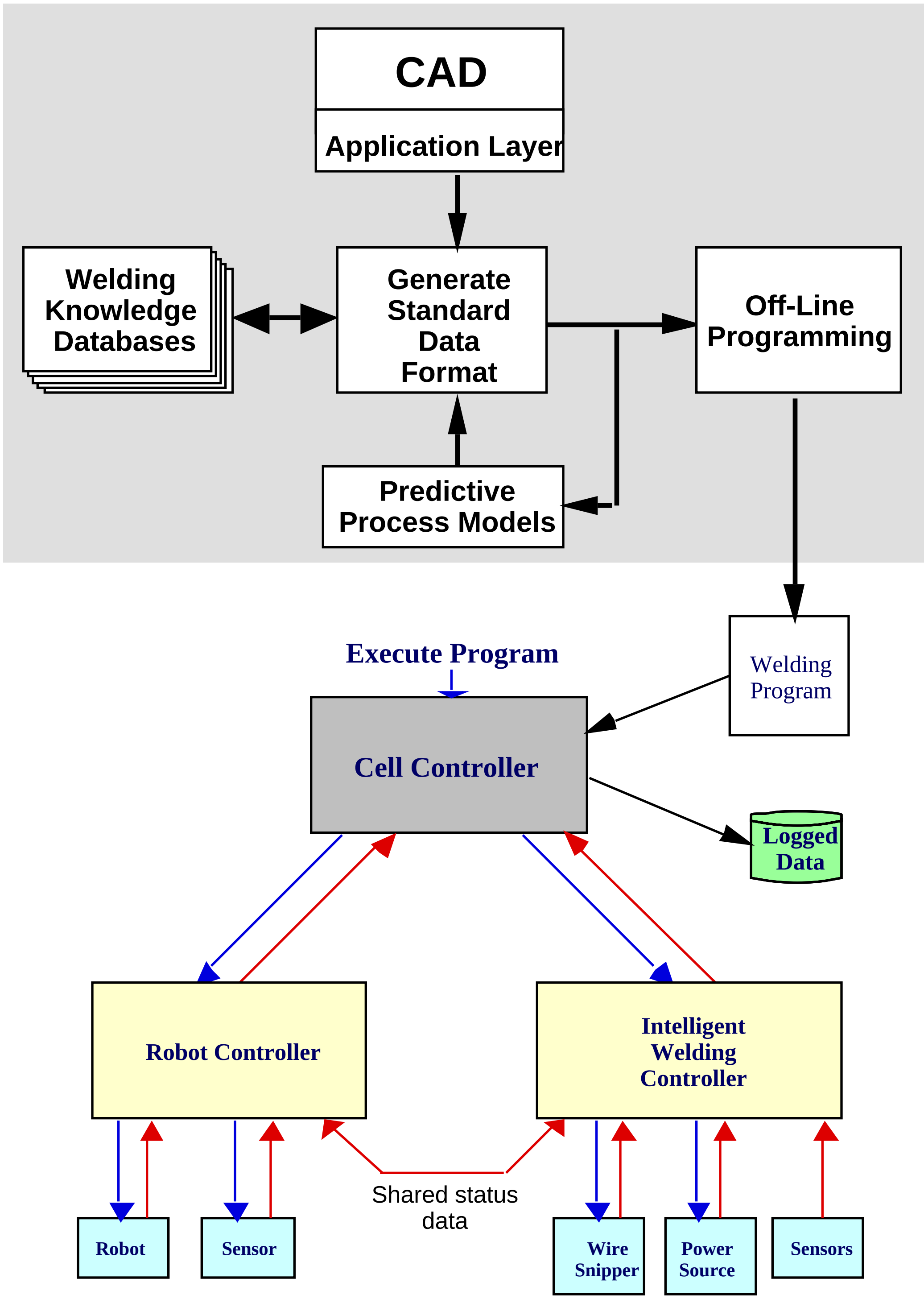

Figure 2. The AWMS logical architecture - control structure and data flow.

Cell Controller

The cell controller supervises both the Robot Controller and the Intelligent Welding Controller (IWC). The Cell controller interprets welding programs that it receives from the AWMS off-line planning system and passes commands based on the weld program to its subordinates. The commands are synchronized based on status updates that the cell controller receives from both the Robot Controller and the Intelligent Weld Controller.

Robot Controller

The robot controller interfaces to the AWMS robot and generates joint commands based on motion commands from the Cell Controller. The robot controller generates motion in either Cartesian or joint space. The robot controller calculates and reports the current torch pose and velocity.

Robot Sensors

The first sensor implementation will use the touch sensing capability of the commercial power source to measure part and weld-joint location. The commercial power source will notify the IWC controller when an object is touching the weld wire. Our initial architecture will have all IWC sensor status signals routed through the Cell controller. Robot touch sensing is implemented through a cell controller algorithm of commanding the IWC to report wire touch status, giving the robot a low speed move command, monitoring the IWC wire status until a touch is reported, sending a stop command to the robot. An alternate architecture is to have the IWC wire touch status conveyed directly to the robot controller and have the robot monitor it and generate its own stop. We are experimenting with both approaches.

Intelligent Weld Controller

The Intelligent Weld Controller (IWC) supervises the wire snipper and the commercial weld power source. It executes commands from the Cell controller and reports status about tasks and its equipment and sensors. The IWC executes welding control algorithms to be tested, and interfaces to sensors and commercial power sources.

Weld Process Sensors

We will test weld process sensors from research and commercial sources, and investigate hardware and software issues of sensor integration into a cell. We hope this will lead to working with sensor vendors and users on hardware and software standards to make adding sensors, or replacing one with another, easy and inexpensive. Our initial sensors are a photocell, and arc current and voltage sensors. These inputs are used by the Arc Monitor System and the Arc Length Controller (Ref. 7), both hosted in the IWC.

NIST BACKGROUND IN SYSTEMS ENGINEERING

The Intelligent Systems Division has over 15 years of experience in the development and application of real-time control technology. We have developed and applied an engineering methodology called Real-Time Control Systems (RCS) to the analysis of problems and the subsequent development of computerized control hardware and software systems. Applications for RCS have included manufacturing control and integration, e.g., the Automated Manufacturing Research Facility (AMRF) (Ref. 14), control of autonomous vehicles, robotic deburring, and robotic crane technology. The scope of the activities includes sensor integration, servo-level control, path planning, off-line task planning, and real-time image processing. (Ref.15)

Our most recent direct research involvement with industry is the Enhanced Machine Tool Controller (EMC) project. (Ref. 1) (Ref.11)(Ref.12)(Ref.15) NIST engineers developed a controller for machine tools, based on open architecture application programming interfaces (APIs) and commercially available components. Two versions were installed on commercial machine tools: a machining center at the General Motors Powertrain Division and a milling machine in a one-person shop near Baltimore, MD. The NIST team collaborated with two controller vendors--Advanced Technology and Research Corp. and a unit of Hewlett-Packard--during the trials at General Motors. The goal is to demonstrate "plug and play" interoperability between such components as motion control and discrete input/output. The installations also help NIST evaluate whether EMC interface specifications are complete, perform as intended, and are compatible with the skills and preferences of factory personnel.

ROBOCRANE

NIST will use another robotic testbed, the RoboCrane (Ref. 5)(Ref. 2), to test concepts of portability and interoperability by moving welding components developed on AWMS to RoboCrane and its control system. The RoboCrane testbed, shown in Figure 3, has been constructed with a six degree-of-freedom work platform suspended by cables driven by winches under computer control. RoboCrane transforms the crane from a device for simply lifting and placing heavy loads into a robot capable of precisely manipulating objects and/or maneuvering power tools with position and force control in all six degrees of freedom. In addition the RoboCrane has a large work volume -- the 6 meter version has a work space of 20 m^3 (686 ft^3).

We have done a quick adaptation of an arc welding torch to the RoboCrane and have done some simple welds. Future experiments will use the RoboCrane to simulate a commercial welding system that will host sensor and control technology developed or integrated into the AWMS.

PLANS

Our 1997 experiments will include weld process monitoring and control, recording and display of weld quality data, sensory interactive robot motion for plate finding, and robotic simulation for program tryout. We plan to add commercial robot sensors for non-contact plate-finding, weld joint location, inspection and/or tracking. This will involve the software and hardware interfaces to integrate the devices as well as software motion and control algorithms to use them. Activities with other organizations and companies will be conducted under formal legal agreements called Cooperative Research and Development Agreements (CRADAs). (Ref. 6)

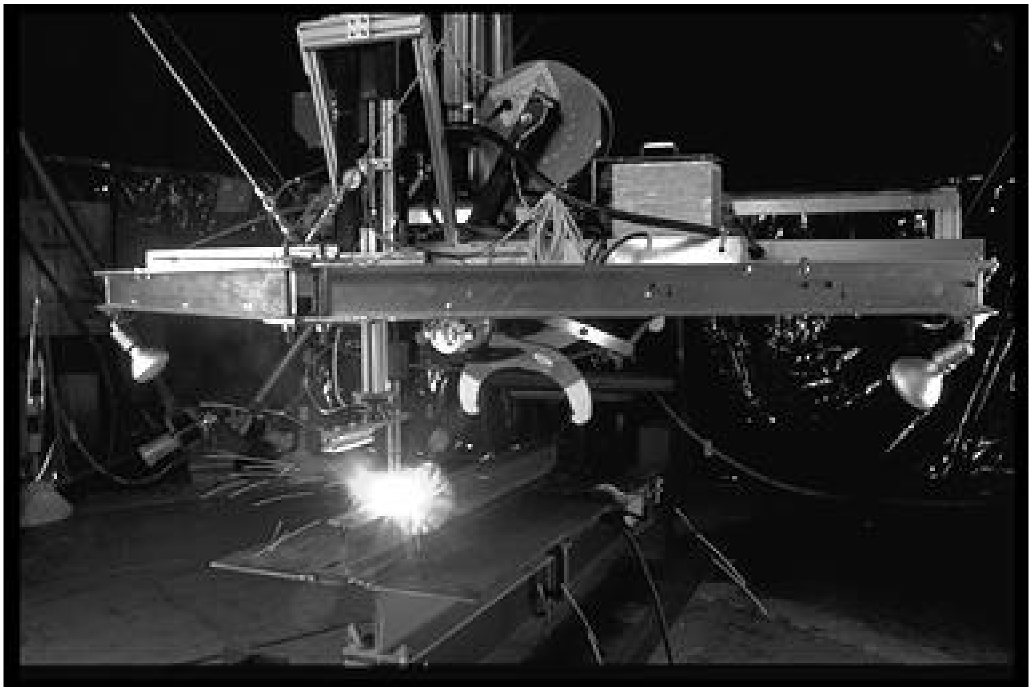

Figure 3. The welding torch is mounted beneath the platform of the Robocrane. The wire feed is mounted above it. Two of the six winch driven cables can be seen at the upper left.

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