CAD interface for automatic robot welding programming

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Research article

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Keywords

Robotics, Computer aided design

Abstract

Industrial robots play an important role in industry, due to their flexibility. Many applications (almost all that require human intervention) may be performed with advantages by robots. Nevertheless, set-up operations, necessary when changing production models, are still tricky and time-consuming. It is common to have detailed data of working pieces in computer aided design (CAD) files, resulting from product design and project. This information is not used satisfactorily, or even not used at all, for robot programming. In this paper, we propose a solution capable of extracting robot motion information from the CAD data.

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Introduction

Robotic welding is by far the most popular application of industrial robots (Books, 1991; United Nations and International Federation of Robots, 2000). Very good research works, achieving very interesting results, were done since the early 1980s, focusing issues like the welding process itself (AGA AB, 2001; Jones *et al.*, 1998; Loureiro *et al.*, 1998; Pires and Loureiro, 2001; Touret, 1997; Choi *et al.*, 1998), sensors (Bolmsjö, 1997a, b; Drews and Starke, 1986; Yada *et al.*, 1986), welding power sources and robotics welding (Adolfsson *et al.*, 1999; Agren, 1995; Bolmsjö *et al.*, 1995a, b; Books, 1991; Dahlén and Bolmsjö, 1996; Pires *et al.*, 2002; Sá da Costa and Pires, 2001), programming, etc. Nevertheless, when robots are used in the shop floor to perform welding tasks, there is still too much additional work to guarantee that they perform with the required quality. The process also takes too long, which means that robots take longer to be programmed and set-up than really doing some interesting work. And that is a problem, since actual concepts like availability and agility (Adolfsson *et al.*, 1999; Agren, 1995; Bolmsjö, 1997b; Bolmsjö *et al.*, 1995a, b; Books, 1991; Dahlén and Bolmsjö, 1996; Kusiak, 1986, 2000; Pires *et al.*, 2002; Sá da Costa and Pires, 2001) are key issues of modern manufacturing. Machines that store high level of flexibility, like robot manipulators, but fail in terms of agility because automation integrators and machine builders were unable, when designing a specific machine, to expose that flexibility to users, may become less interesting. This is one of the major issues that robot manufacturers must address clearly in the near future.

When robots are used to weld, the programming problem arises immediately. In this paper, we address this issue by presenting a CAD interface enabling fast and simple programming. The paper is organized as follows. First, the CAD interface is introduced and explained, along with the experimental system used to test the proposed solutions. An industrial test case example is then briefly presented and discussed. Finally, conclusions are drawn together with guidelines for future work.

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CAD interface

Currently, since the vast majority of companies use CAD programs to design their products, information from CAD files could be used to generate robot welding programs. The application presented here enables the user to work on the CAD file, defining the welding and approach/escape paths between two consecutive welds, and organize them in the desired welding sequence. When definition is complete, a small program converts it to robot commands that can be immediately tested for detailed tuning. A set of tools is then available to speed up necessary corrections, which can be made online with the robot moving. After a few simulations (robot performing all motions without welding) the program is ready for production. The whole process can be completed in just a few hours, representing a huge reduction of programming and set-up time. Following the current developments available in the Industrial Robotics Laboratory of the Mechanical Engineering Department of the University of Coimbra, and meeting a request from the industry, a solution was designed using AUTOCAD and DXF files (currently standard files for all CAD software tools). If the user follows some basic rules, and produces a DXF file with all the information needed, then the application developed is capable of extracting that information from the CAD file, and is able to produce a robot program almost ready for production.

The user starts by having a 3D drawing of the piece to weld and of the table used to hold the piece. The 3D models should be very precise in dimensions and in part positioning. Then the user should draw (Plate 1) all the trajectories required to fully weld the piece as desired, using the available layers, i.e. using one layer for each trajectory, which is composed of a start-point and an end-point, both with orientation, and the type of motion (welding trajectory or approach/escape trajectory). The welding parameters (velocity, voltage, torch distance to the surface) are introduced in the selected layer, just by adding labels with the corresponding values. The weld layers should then be renamed for easy identification. Following this simple small set of rules, the designer can add to his 3D models information about how the welding process should be done.

The DXF file generated by the CAD application (AUTOCAD in our case) includes all the information added to specify the welding process. Since the DXF file is an ASCII file, it is very easy to extract the above-mentioned information, using a simple application (Plate 2) that identifies each added welding layer, and the related welding parameters, and stores all that information in a known way. Here the definition shown in Figure 1 was used.

The generated dat file is used as input for the application shown in Plate 3. This application shows the available definition with the help of several push-down buttons, and enables the user to change the welding parameters, correct points and orientations, simulate the whole process using the real robot and the real piece to weld. The simulation is very realistic, making the final program ready for production.

Test case example

The laboratory set-up (Plate 4) is composed of an ABB IRB1400 M94/S4 industrial robot, equipped with a ESAB A350 welding power source controlled from the robot using our own software (we do not use any of ABB WeldWare software modules), and a RPC-based software interface to a PC (RAP, 1996), explored using the software package PCROB (Pires and Sá da Costa, 2000; Pires *et al.*, 2002). PCROB is a collection of software tools that enable control of the robot from a PC. In our case we use a Pentium II PC running Windows 2000/SP4.

The piece used in the proposed example (Plate 4) is a scale model of a piece very common in companies building structural components for the construction industry. A 3D drawing of the selected piece and holding table (Plate 5) is then necessary to proceed. Subsequently, the welding trajectories should be added as explained earlier to completely define the welding process.

The test weld is very simple and is shown in Plate 5 connecting the topside from left to right. The welding parameters were selected using a welding database (The Welding Institute, 2000) by taking into consideration the material in the test piece.

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Plate 1 Example of welding trajectories using available layers

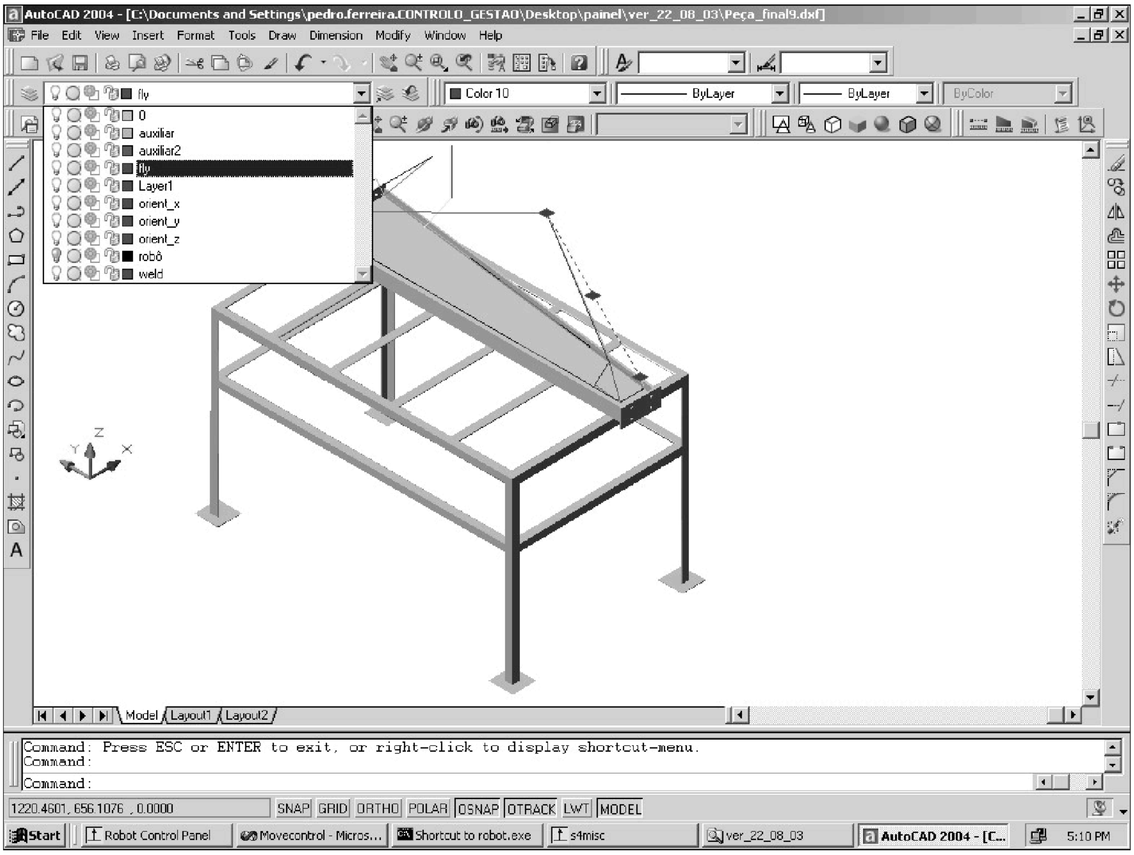
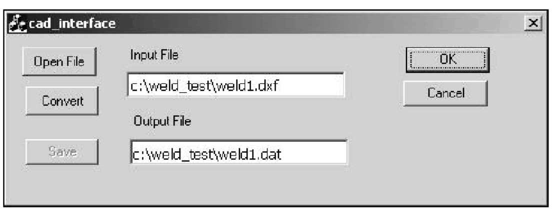


Plate 2 Application to extract information from a DXF CAD file



The results obtained in this test case were very promising, since it was possible to make the weld less than 5 min after finishing the CAD model of the system, just by generating the DXF file, extracting the information to the simulation application (Plate 3) and make a few adjustments to solve any small positioning errors, and testing everything using the simulation facility of the tool represented in Plate 3. A video of the system performing can be found in http://robotics.dem.uc.pt/norberto/cv/videos/pedro_welding.wmv, where only the welding process is shown.

Conclusion

In this paper, we presented a CAD interface capable of adding in the programming process of welding applications. The solution has proved to be very interesting, permitting a big reduction of the programming process just by extracting welding definition from the CAD file, and enabling a fast pre-program that is very easy to simulate and adjust. The system was tested using linear welds on a piece, built to scale from real structural pieces for the construction industry, and showed to be accurate and very easy to use. Further development is needed in a way to define all the situations that may arise in industrial environments. Nevertheless, the results obtained show that a general solution is possible just by adding simple rules to match each case.

Further developments should be carried out just by making the solution compatible with other robots/controllers. This requires standard software and platforms, refusing to use proprietary licenses and protocols.

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Figure 1 Definition of the welding file obtained from the DXF CAD file

	Simple_Test_Example	Name of the file
	4	Number of points in this file
	Point 1	Point number x
Definition of point 1	Origem	Name of the point
	1	Type of point (welding – 0, approach/escape – 1)
	656.419922	x
	-444.451813	y
	730.853149	z
	0.091980	q1
	0.001690	q2
	0.995760	q3
	0.002070	q4
	0	cf1
	-1	cf4
	0	cf6
	0	cfx
	8999999488	ex1
	8999999488	ex2
	8999999488	ex3
	8999999488	ex4
	8999999488	ex5
	8999999488	ex6
	0.00	Intensity [A]
	0.00	Voltage [V]
	100	Velocity [mm/s]
	5	Precision
	0	Motion type (linear – 0, circular – 1, joints – 2)
	...	
	Point 4	
Definition of point 4	End	
	1	
	684.311096	
	-443.820709	
	581.514465	
	0.092050	
	0.001700	
	0.995750	
	0.002130	
	0	
	-1	
	0	
	0	
	8999999488	
	8999999488	
	8999999488	
	8999999488	
	8999999488	
	8999999488	
	0.00	
	0.00	
	10	
	5	
	0	

Plate 3 Program used to adjust program obtained from CAD file

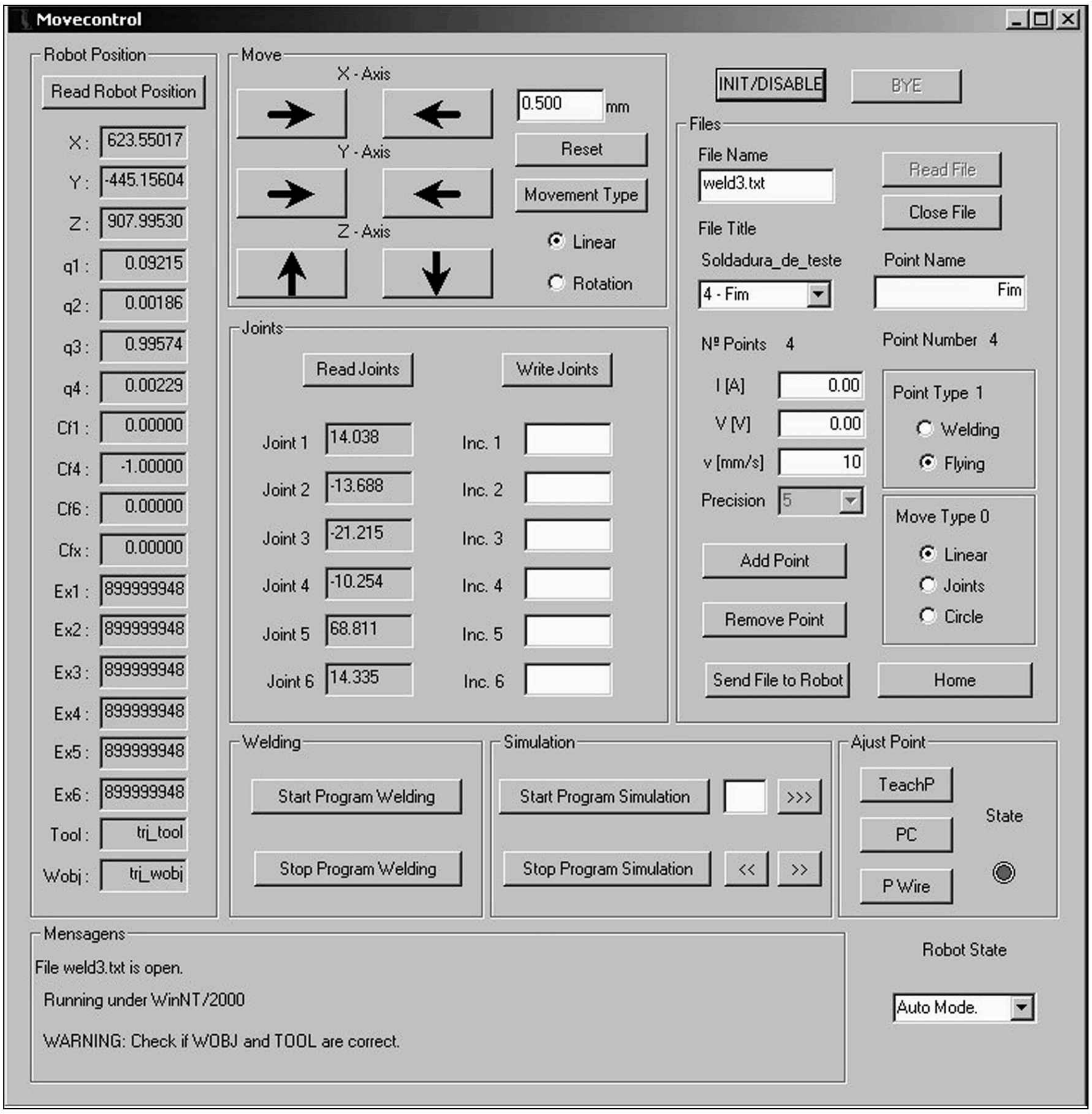
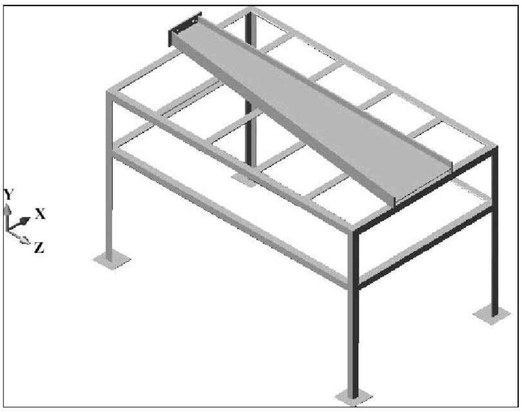


Plate 4 Aspect of the experimental system and test piece

Plate 5 3D drawing of welding table and selected piece



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