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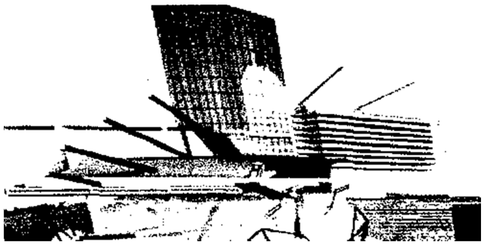

HOUSING CONSTRUCTION

An Interdisciplinary Task

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University of Coimbra - Faculty of Sciences and Technology Depa il E -
Constructions Laboratory Portugal

The Use of Robots in the Construction Industry

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Abstract

This article first explains why it is currently not feasible to use robots on construction sites. The authors argue that robotics will be utilized in the upstream industries, either in component manufacture or in constructive processes capable of being undertaken in a traditional factory setting. Although the former would be a simple way of incorporating robotics into the construction industry, the second would have major implications for the constructive process that extends from the project design phase to the technologies employed on the building site.

1 Introduction

Robots are used today in several industries [4,5], the best known example of which is the car industry. Essentially, they replace workers engaged in intensive manual labour, especially for repetitive tasks.

However, in most industrialized nations, the construction sector is among those mobilizing the greatest number of economic resources. In Portugal, for example, if we look at the sectoral interrelations via a Leontieff matrix, we can easily see that it engages around 40% of the economy. One of its chief characteristics is enormous labour costs, which account for almost 50% of the total, though there are considerable variations, depending on the type of project and works involved.

If robotics aims to replace men with machines, then the construction industry is a vast field for the development of its applications.

2 Robots on the Building Site

When considering using robots for construction, the building site has to be characterized (see also [1,2,6]), as this is a production site *par excellence.* The working environment and types of task to be carried out have to be borne in mind:

Building sites have a considerable geographical dispersion, especially those owned by the largest companies;

The final products are not considered repetitive, since each project is unique;

A large number (hundreds) of different activities are carried out on building sites, with little repetition;

On sites, many tasks are being done at the same time, and they are interlinked in terms of the resources allocated to them;

Building sites are relatively dynamic places, with systematic changes of jobs and the surrounding environment;

Building sites are hostile in that they are replete with obstacles, uneven surfaces, ladders, spans over empty spaces, etc.;

They are unstructured to the extent that they are not set up to have known references for the movement of robots;

The tasks involved are complex in the cognitive sense, and they therefore require knowledge from experience and the use of certain sensory capacities;

Even tasks with repetitive operations would require the robot to systematically change position, usually by shifting orientation so that it could begin a new cycle.

All this implies that using robots in practice, on actual work sites, would depend on their being portable, being able to move around, to "sense" the environment, to process the data and information received and, based on all the information available, to perform a task. As building sites are unstructured localities, they present a considerable challenge to mobility and recognition of the workplace environment.

For the use of robots on actual building sites to be effective we would have to concentrate especially on the domains detailed below.

Locomotion: robots would have to be able to move about with a certain degree of "intelligence", which implies providing them with the means to go up ladders, cross spans, avoid obstacles; that is, the means of locomotion implies the existence of viable paths. This situation is quite different from real building sites, where surfaces are not smooth, but are littered with rubbish, materials stacked ready for use, obstacles, etc. They would have to provide the means for guidance, or organize pre-defined routes (likely to be repetitive), or structured environments with references identifiable by robots.

Vision: most of the capacities required imply the use of artificial vision, with recognition of the range of environments in which the robot operates.

Being prepared for hostile environments: robots should be ready to work outdoors, moving around in difficult conditions, unprotected and subject to the unexpected, such as falling from heights, falling materials, impacts, atmospheric agents, etc.

Handling unwieldy or heavy loads: robots could perform tasks involving the handling of heavy loads, such as beams or prefabricated panels (which can weigh several tonnes), and large elements. Handling fragile materials: robots could handle breakable materials, like some ceramic products (tiles, bathroom fittings) or glass.

Current technology in the domain of robotics could overcome each of these difficulties. This would not, however, be economically viable, even if major changes were made to building sites. The use of robots in construction should only be undertaken away from the problems intrinsic to building site environments and upstream of their utilization in the job. The hypothesis that seems to offer the best chance of taking the greatest advantage of robots today lies in carrying out repetitive tasks, on a large scale and with a fixed job, in a factory situation.

To benefit from the potentials and virtualities of advances in robotics it would be necessary first to modify the conceptual understanding of the construction industry, more specifically, the construction process itself.

3 Robotics in Pre-fabrication

By having robots carry out tasks in factory environments, where there are no problems in terms of moving around and identifying the place of work, we come up against implications and problems related mainly to pre-fabrication.

In terms of technology, designers would have to adapt their plans to use components provided by pre-fabrication, reducing, as far as possible, the amount of elements made on site. Preparation of the works on site would thus become more important. In execution,

with the prior manufacture of components to be incorporated into the job, construction would increasingly become an assembly industry.
With respect to the economic implications of producing the elements to be incorporated into buildings, construction would be more and more reliant on the upstream industry. The viability of these firms would depend on sales volume. This in turn would be critically dependent on the popularity of their products and the capacity of the company to produce them at a cost that justified the change in technology. It should also be mentioned that, in many countries, jobs are overwhelmingly carried out by low-cost labour, and immigrant workers are frequently employed. In Portugal, for example, after decades of African workers, there is now an influx of emigrants from Eastern Europe. Ukrainians, Moldavians and Romanians are now commonly seen on our building sites.
Regardless of these implications, it should be stressed that some robotics systems have the potential for immediate use in the environment of pre-fabrication for the construction industry. Robot manipulators in particular have features and a level of technical development that are quite capable of meeting the demands of the tasks in question. In this domain, the advance of robotics technology could make it applicable in a good many construction processes. Industrial robot manipulators are essentially machines with control over position and movement, to which work tools can be adapted. In addition, they have a high degree of precision and speed of execution, can accept several communication interfaces, have various input/output possibilities, force control, visual servoing [3]. But they need to be integrated and adapted to the specific manufacturing requirements, in terms of both working tools and programming.
Next we shall look at an implementation that is in progress.

4 Case under Development

The case we shall now examine is still being developed. It is designed to install robot manipulators in one of the country's leading metal construction firms. The project is headed by the Robotics Laboratory of the Department of Mechanical Engineering in the University of Coimbra. The robots' work will be to solder metal structures.

The system being implemented (Figure 1) comprises a FANUC industrial robot, a welding machine and a personal computer running Windows NT 4.0 or Windows 2000. This computer will be used for modeling, monitoring and controlling tasks, and should include Visual C++, Basic or Matlab programming tools. It will also use software for controlling, programming and monitoring the robot.

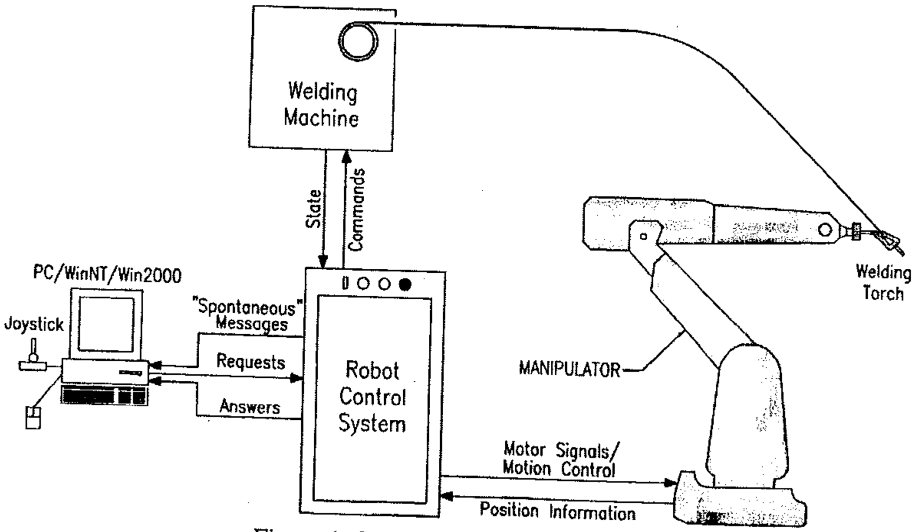

Figure 1: System being implemented.

It should be noted that the connection to the programming environments (Visual C++ and Basic), to mathematics environments (Matlab), and other tools for analysing and presenting results (Excel, etc.) capable of real-time intervention, mean that a powerful setup for R&D uses can be obtained, as is desired for robotized welding.

It is hoped to develop procedures for this technological process that will make it possible to simplify and characterize the preparation phase (setting up all the parameters and trajectories), and to identify a minimum (but sufficient) group of parameters for monitoring the way to achieve welding of constant quality, within pre-defined ranges.

The first goal is thus to characterize and define the interface with the user (which implies understanding the production process) and defining the kind of information to be requested.

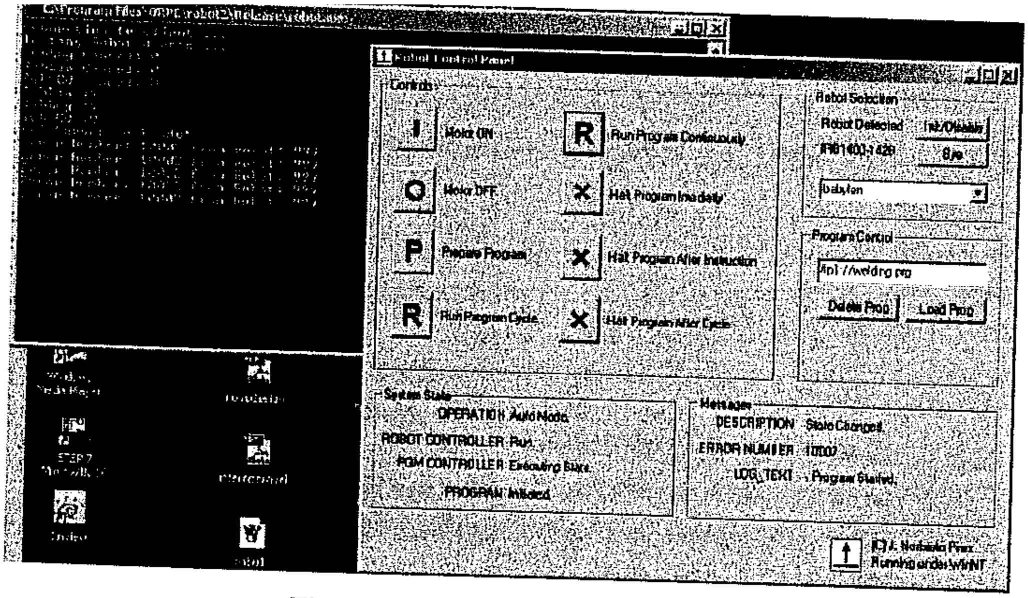

Figure 2: Control panel for robot.

For this purpose, it is intended to use robots together with an architecture database that contains all the variables of the welding process and the dimensions of the pieces to be welded, the weld points programmed for the beginning and end of the operation. This database will help to reduce the work times related to changing the product, adjusting and programming the robot (Figure 3).

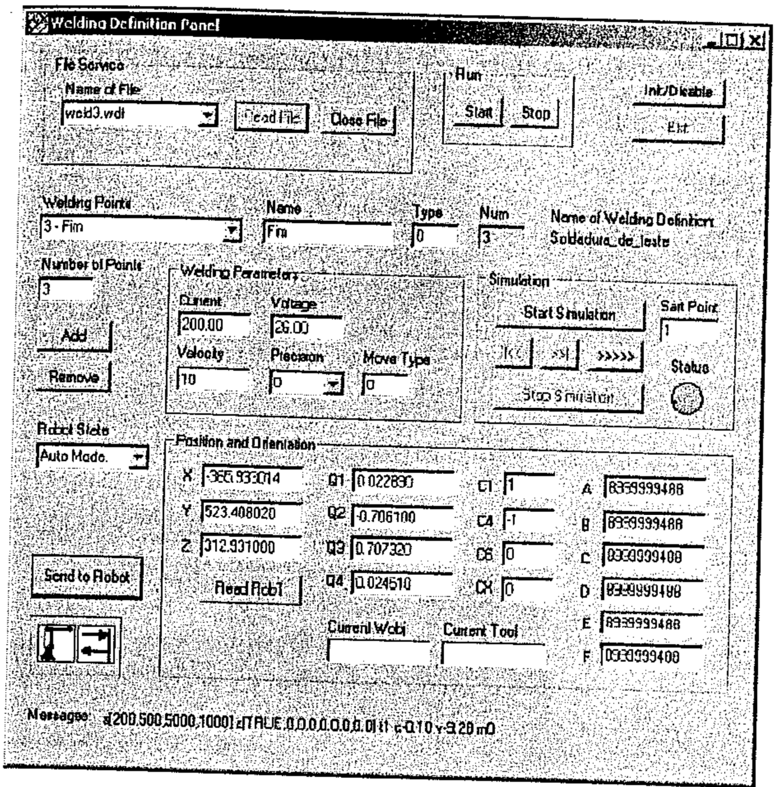

Figure 3: Welding definition panel.

For current manufacturing operation, it is intended that the operator should choose a product code and thickness from the database. All the variables will be listed ina a dialogue box; the operator should determine three or four spot welds, and their parameters, if necessary (Figure 4). Once adjustments have been made, the operator starts the programme cycle.

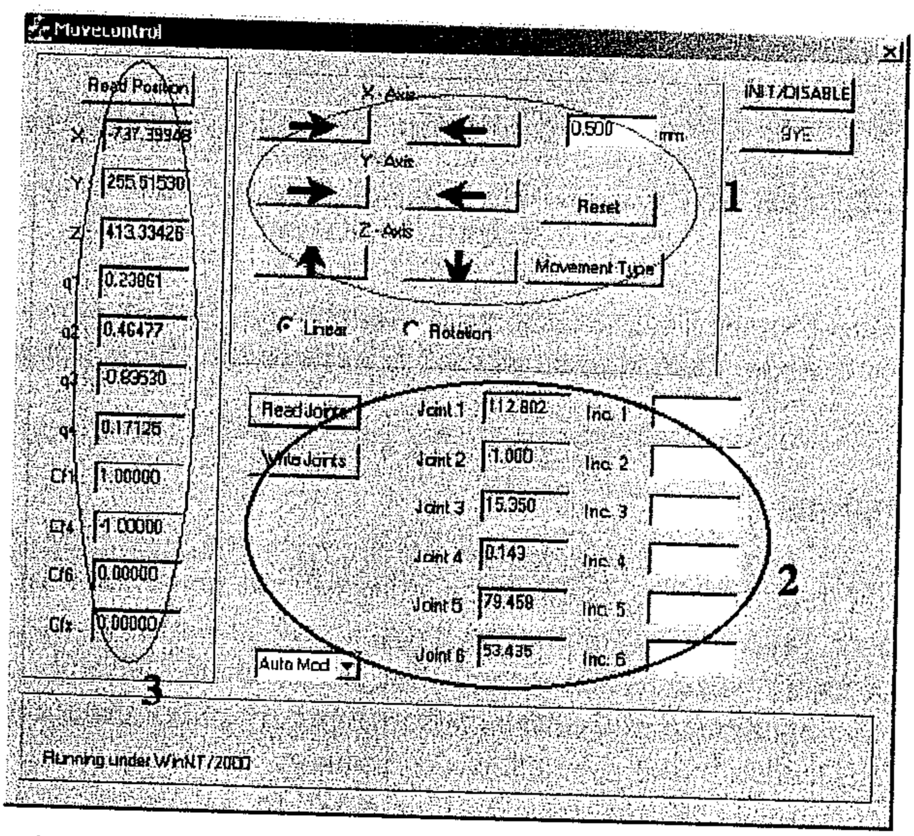

Figure 4: Welding control panel, with (1) being the XYZ Cartesian movement control, (2) the joint movement control and (3) the robot position.

The robot can then begin or end a welding procedure, it can be commanded to follow trajectories (wholly simulated) or to proceed with the welding, step-by-step. For this, the user sends the full definition of the task, including welding spots and parameters (speed, tension and intensity), type of trajectory and precision, all of which information is stored in a file (Figure 5).

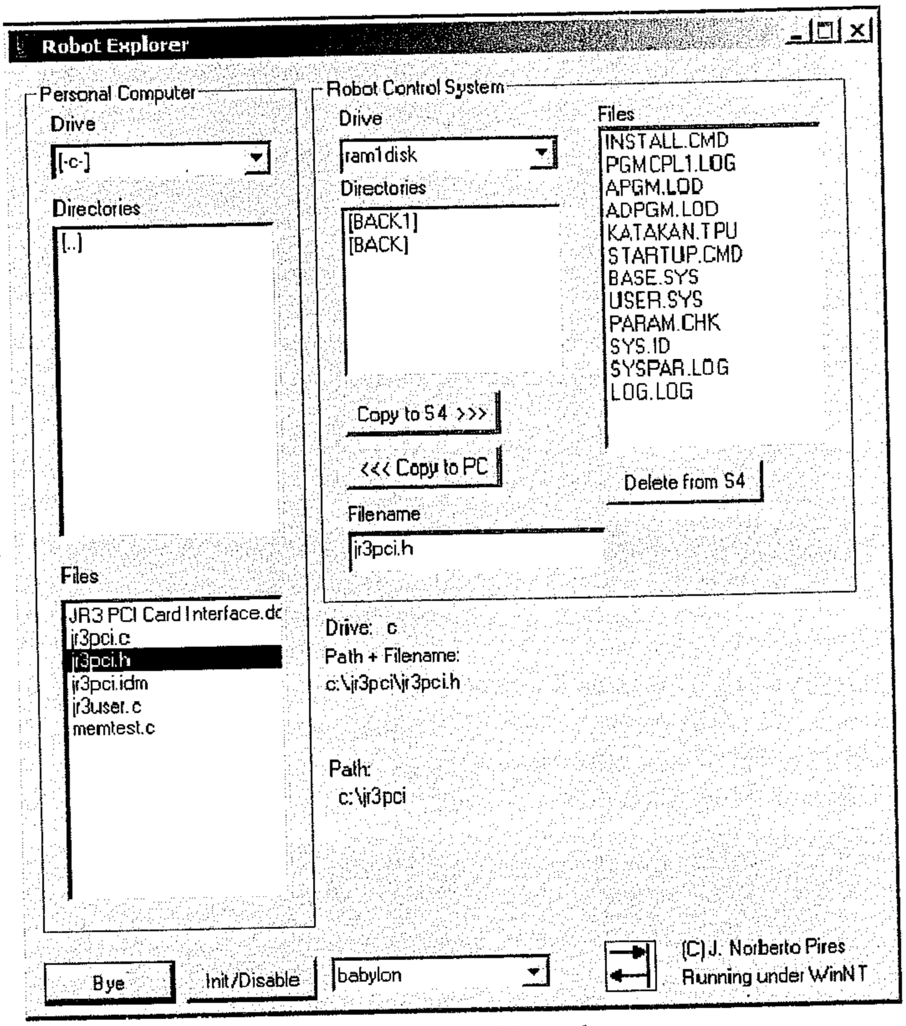

Figure 5: Robot's file explorer.

This information can be reused countless times, forming production routines that the operator can use whenever the components to be welded have the same characteristics.

5 Conclusions

The possibility of incorporating in building a significant percentage of pre-fabricated elements, produced by robots, assumes the existence of an industry upstream in which manufacturing tasks are performed in a controlled environment, and not on site.

Cheap labour is an impediment to significant change in current construction processes, and to the large-scale introduction of robotics in this industry.

While research continues in this area, implementation will increase in fields where productivity gains outweigh the equipment and implementation costs.

Robot manipulators are now a good investment, given their possibilities and flexibility.

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