TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics
Vol. 55, Issue I, 2012

CURRENT TRENDS REGARDING THE INTUITIVE PROGRAMMING OF INDUSTRIAL ROBOTS

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Abstract: *This article presents the current state of the art regarding the intuitive programming of industrial robots. The paper explains the need of increasing the usability of industrial robots programming interfaces in order to increase the number of industrial robots used in SME (Small and Medium Enterprises).*
Key words: *industrial robots programming, human-machine interface, intuitive programming, user centered design.*

1. INTRODUCTION

Developing communication and integration standards, as well as providing features that increase the safety of operators, are some of the major challenges in industrial robotics. Nowadays human–robot interaction is an emerging research field, aimed to facilitate an easy integration of robotics system in industry.

Developing intuitive programming means, based on user centered design (UCD) concepts, attempts at optimizing the human-robot interaction so that users no longer need to change their operating mode depending on the adopted robotic technology. An ideal UCD programming environment would adapt to the operator's habits and needs, not vice versa [1].

Intuitive programming of industrial robots refers to the development of software application through which the user can interact with the robot as easy and natural as possible, with no need of programming knowledge. Intuitive software must be easy to use even if the user is unfamiliar with it, and at the same time has to remain complex and stable so that the operator may create reliable applications.

Now that mechanical development of industrial robots has reached a high maturity level, most of the research and studies are dedicated on improving the control of industrial robots. The improvement of robot control methods is aimed at increasing the performance of the robots, at encapsulating new features and functionalities, and at reducing production costs [2].

2. ECONOMIC NEED FOR THE DEVELOPMENT OF INTUITIVE INTERFACES IN PROGRAMMING INDUSTRIAL ROBOTS

Generally, the programming of robotic capabilities is performed with the help of the teach-pendant, in the case of cells comprised of one or two robots, or by offline method where an entire production line may be programmed and tested in advance [3]. But both of these programming methods are applicable only for high or medium production batches because it requires long and extensive programming experience. Figure 2.1 shows the link between the production batch size, degree of automation relatively to the programming method. It can be observed that the unique pieces are made by workers.

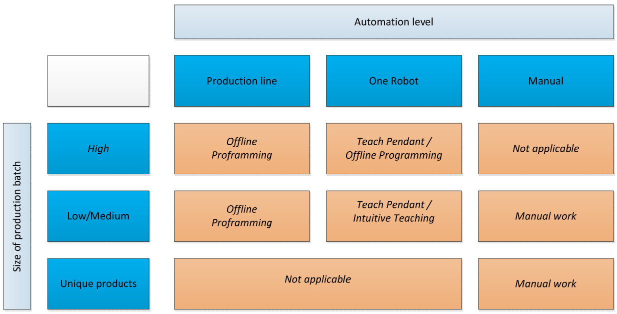

Fig. 2.1 Correlation between production batch size and industrial robots penetration/use

Industrial robots, compared to others automatic machines, have two main advantages, namely: a high flexibility and a good handling, and industrial robot producers are relying on this when trying to broaden their market by introducing robotized production lines in SME.

The current paradigm for this market segment is governed among other by rapid production changes and also by the lack of experts in the domain of robot programming.

All this emphasized the pressure of implementing, at production cell level, of a set of assistance and help mechanisms that will reduce the dependence of SMEs on external programming experts for minor tasks such as reconfiguring existing applications. Those kind of mechanisms will enable the staff of SMEs to program the robotic cell without attending programming classes, so without prior training concerning the advanced programming of robot controllers.

3. HUMAN MACHINE INTERFACES FOR INDUSTRIAL ROBOTS

With respect to robotic production capabilities, we may classify the Human-Machine Interfaces (HMI) as follows:

- *command line interfaces;*
- *graphical user interfaces – GUI;*
- *touch user interface – TUI;*
- *multimedia interfaces (voice, animation, multiscreen, zooming);*
- *intelligent interfaces (gesture recognition, conversational interfaces, etc.).*

Industrial robots producers have incorporated into the last generation of their products a mix of graphical and touch user interfaces [4],[5]. Compared to command line interfaces, this new approach (GUI & TUI) offers a better learning curve, but still requires hundreds of training hours in the field of industrial robots programming.

In the case of on-line programming, the interface between the robot controller and the human operator is a device called the teach-pendant.

The operator uses the teach-pendant for tasks such as:

- *robot movement;*
- *selecting the running application;*
- *testing the application;*
- *setting parameters concerning the production process;*
- *checking the status of the robot (health status, undergone activities, program status, etc.);*
- *manual programming of the robot;*
- *application configuration and fine tuning.*

Robots controlling is a major challenge for the big producers, thus research is done to increase the robots performance, to minimize the costs and to add new features to the robots [2].

The research community is focusing its efforts on two major directions:

- *human-robot interaction in order to facilitate the positioning of the robot by hand;*
- *multimodal interfaces (multiple devices) communication for robotic cells.*

The most important researches that are being carried out at the moment are:

- *multi-robot control;*
- *safety control;*
- *force control;*
- *3D vision systems with applications on robot capabilities management;*
- *wireless communication for robotized production cells;*
- *distant monitoring of robotic cells.*

3.1. Classification of Industrial Robots Programming Methods

The U.S. Occupational Safety and Health Administration [6], [7] has defined three common methods used in the case of industrial robot programming:

- *Lead-Through Programming or Teaching.* This method of programming implies the use of a teach-pendant that allows qualified personnel to move the robot into desired positions or to run existing program sequences. In some cases the producers developed virtual console applications that may replace the use of the physical teach-pendant.
- *Walk-Through Programming or Teaching.* In this case the operator is gaining control of the robot by manipulating the end-effector with his hand and thus positioning it in the desired location within the robot working space. The controller of the robot is recording the coordinates for the path/points where the robot arm is moved, so that the robot may replicate the exact path earlier described by the operator.
- *Off-Line Programming.* This programming method implies the use of a software product installed on a PC, which allows the programming of a virtual production cell (identical to the real one). The program that contains all the positions and functional sequences is then transferred into the robot controller.

3.2. Studies concerning the improvement of industrial robot programming methods

Even if the first attempts at programming industrial robots by means of Walk-Through [8], [9], [10], have shown that this method of programming industrial robots can be useful, the positioning of the end-effector into a certain point requires a series of translations and rotations that may be difficult or time consuming.

Since the variability and flexibility in industrial production processes is becoming increasingly high, and since there is also a trend towards micro-production series and custom made products, a frequent human-robot interaction is obviously needed in order to calibrate and change the production process to specified requirements or even to reprogram the tasks and trajectories.

To facilitate this, a series of application by which man interacts with the robot via force sensors placed on the robot were implemented [11], [12].

Similar programming principles [13], [14], [15], [16], [17] were used to develop applications where the robot is positioned in various points by means of force sensors (Figure 3.1). This programming method is considered among the most intuitive and simple ones for the operator.

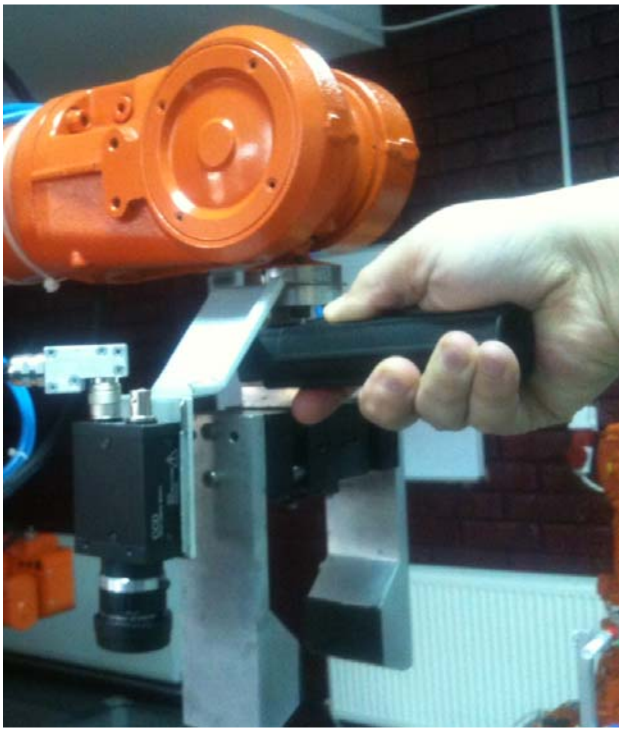

Fig. 3.1 The use of force sensors for robotic cells programming

The user guides the robot by means of a device which has attached to it a sensor that determines the strength of the couple. Robot movements are driven by a strategy based on force as an input element. The trajectory described by the user is stored and can be reproduced exactly by the robot arm. Before setting the robot in motion the operator my change parameters such as: speed, position and orientation, thus allowing a greater flexibility.

This is a new approach in programming industrial robots and is currently being used only for painting processes. This programming method presents several advantages over traditional ones:

- *the operators may be trained in less than a day in programming the robotic cell;*
- *robot programs can be changed easily and rapidly, thus offering more flexibility in terms of product variation;*
- *this method allows for more production time as it reduces the programming time.*

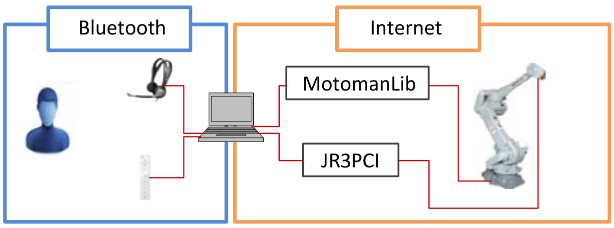

Fig. 3.3 Wirelless programming example (after [21])

Another programming approach is the use of various communication devices for controlling and manipulating the robot. Researches towards enabling the user to perform a welding process using voice commands [18], [19], [20] or by means of "remote control" like devices [21] clearly shown that this method of programming can be implemented by producers in future industrial robots (Figure 3.3).

There are some industrial fields where an increased personal hazard is reported, the robot producers are trying to solve this problem by developing technologies for programming the robotic cells with the help of wireless communication equipment [22]. An example is the programming of robotic applications using a PDA (Personal Data Assistant). Among the advantages presented by this approach we may point out some of the most important:

- *workers safety is increased as they are able to program the robot from a protected area;*
- *the operators are free to move as there are no cable connecting them to the controller, thus allowing for an easy movement along the production line;*
- *the applications may be programed from other locations, so there is no need for physical presence.*

Another method of programming industrial robots is Off-Line Programming, where the user programs and tests the application destined for the production cell in a virtual environment and then transfers the application to the robot controller. The advantages of Off-Line Programming are:

- *reduced production downtime due to programming of new applications;*
- *the ability to remotely program the robots, thus reducing personnel hazard and reducing costs due to external experts travel.*

Every industrial robot produces has developed its own off-line programming environments: ABB – RobotStudio, KUKA – SimPro, Fanuc – RoboGuide, Motoman – MotoSim, etc. One of the major shortcomings of those environments is that they facilitate only the programming of robots produced by a certain company.

In order to overcome this drawback, research is being done towards the creation of a virtual programming environment that will facilitate the integration and control of heterogeneous robotic capabilities (different producers, different generations) into the same production cell. With this respect, a Java implemented software [23], [25], [25] proves that various industrial robot technologies may be successfully controlled from a single application, e.g. equipment produced by ABB, Fanuc and Mitsubishi.

4.CONCLUSIONS

Even if the Walk-Through approach is the most intuitive and easy way of programming an industrial robotic cell, one has to take into account that the positioning of the industrial robot end-effector is only approximately 5% of the software program, the rest of 95% being dedicated to logical functions, interactions with other devices and equipment, definition of input and output signals, tools definition etc. So the challenge is to develop an expert system that will support the inexperienced operator in planning and developing an application for a robotic cell.

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ACKNOWLEDGMENTS

This paper was supported by the project "Doctoral studies in engineering sciences for developing the knowledge based society-SIDOC” contract no. POSDRU/88/1.5/S/60078, project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

This paper was supported by the project "Development and support of multidisciplinary postdoctoral programmes in major technical areas of national strategy of Research-Development - Innovation" 4D-POSTDOC, contract no. POSDRU/89/1.5/S/52603, project cofounded by the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013.

Tendințe actuale privind programarea intuitivă a roboților industriali

Abstract: *Acest articol prezintă stadiul actual al cunoaşterii privind programarea intuitivă a roboților industriali. Lucrarea dezbate nevoia creşterii utilizabilității modalităților de programare a roboților industriali în vederea măririi gradului de penetrarea a roboților industriali în cadrul întreprinderilor mici şi mijlocii.*

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