Programming and wireless control of a wafer manipulation SCARA robot using a mobile device

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Abstract. The research performed by the authors had the purpose of developing a control and programming application for a 3-axes SCARA robot designed for wafer manipulation and integrating it with a mobile device capable of wireless communication. The mobile device was then used to command axis movements, internal signals and for programming. The application was developed as a user-interface capable of communicating with robot's controller and converting the user inputs into controller commands. In order to achieve position control, the direct kinematic model of the robot was developed. Furthermore, the application was integrated with the V-REP virtual simulation platform in order to achieve simulation and offline programming capabilities - the V-REP software provided the 3-D environment and the kinematics modelling functions required to perform the simulation while receiving commands from the developed application. Finally, a few demonstrative applications were configured in order to test the functionality of the system. The research has important implications in the field of industrial wireless communication, being a step towards more flexible robotic applications, full integration of remote operation technologies and easier access to remote production facilities.

1. Introduction
The industrial robotics field was always characterized by flexibility both regarding the kinematic structure of the mechanical system and regarding the application in which the robot is integrated. Another one of the main advantages is represented by the opportunities for automation, sensor integration and adaptive feedback control. All these advantages are based on communication capabilities of the robot systems. Thus, the communication method is a very important aspect when developing robotic applications [1]. While there are certain well documented, well developed and integrated communication standards, new approaches and advances in this field could open new future opportunities for industrial robotics [2].

The purpose of the research illustrated in this paper was to develop a remote, wireless control and programming interface for a 3 axes SCARA robot. The direct focus of the development was a JEL wafer manipulating robot that had a very basic controller, no teach pendant and no power supply. The only available programming method was by sending specific commands to the controller through serial interface from a computer, and the movement could be done only in joint coordinates, axis by axis. The opportunity was linked to the fact that the system could be used as an openly available base platform [3].

This research article illustrates the development of the ControlJEL software interface for the above mentioned robot system, its integration with the V-REP virtual robot experimentation platform –
capable of providing an offline programming and simulation environment – and the configuration, using these resources, of a few demonstrative applications in order to test the functionality of the system and to explore future research opportunities using this platform. The ControlJEL software was developed specifically to be functional when running both on a computer which connects to the robot controlled through a wired communication using the USB port and on a mobile device running either Windows or Android operating systems or which connects to the robot through wireless communication using the Bluetooth protocol.

2. Research objectives
The objectives of the research project are presented below:
- To restore the functionality of the JEL robot by integrating a new, compatible power supply.
- To identify the most important commands recognized by the robot controller, especially those linked to axes movement control.
- The development of a programming and command software interface compatible with mobile devices which can be used as a wireless teach-pendant for the robot.
- The configuration of the direct kinematic model in order to integrate direct position control.
- The development of an accessible programming language for the ControlJEL interface specifically aimed at compatibility with the JEL robot functionality in order to achieve robot programming capabilities.
- Integration in the ControlJEL software interface of robot point-to-point teaching capabilities
- Integration of a Bluetooth communication module for the JEL robot and implementation of the communication protocol between the robot and the software interface in order to achieve wireless communication.
- Implementation in the V-REP environment of the 3D model of the robot together with kinematic configuration in order to gain offline programming and simulation capabilities

3. Equipment and resources
Figure 1 illustrates the proposed communication logic of the system. One of the objectives was to achieve communication between a smart device running the ControlJEL application and the robot. The system was intended to be used both through wired communication using the USB port and through wireless communication using the Bluetooth protocol. The diagram in figure 1 shows the approach of using the Bluetooth communication through the RC232C to TTL adapter by using an Arduino Uno microcontroller (shown in figure 2) [4]. Basically, for this approach, the Arduino board is used as a relay, allowing direct bidirectional information transmission to the robot.

![Communication logical structure](image-url)
The Lua programming language, developed at the Pontifical Catholic University of Rio de Janeiro, is a lightweight, cross-platform language that is supporting more than one programming paradigm and which is used for embedded integration in a broad range of applications, including at industrial level. The main advantages of this program are high portability, adaptability, opportunities for quick software development, does not require compiling and can be extended with multiple libraries. The main disadvantage is that Lua is slower than programming languages that compile in assembly, for example C++.

Love2D is a framework that can be used to develop 2D graphics with integration of sounds and input capabilities using the Lua language. The framework is open-source and works on both Windows and Android (x86/x64 architecture, as well as ARM architecture), advantages that made it a good choice for the interface development. in order to establish communication with the robot and the Arduino module, a special library called serial.dll was needed.

The JEL robot, model SHR31583 is a 3 axes cleanroom type industrial robot with a SCARA architecture developed for wafer manipulation. The workspace of the robot has a cylindrical coordinates structure, with a column that can slide along a vertical axis (the first axis of the robot) and the arm which can describe motions in polar coordinates. The second and third axes of the robot are represented by the rotation of the arm around the axis of the column and the extension of the arm respectively. The extension of the arm is ensured through three rotary joints actuated by a single motor, the rotation movements being synchronized through the ratio of the belt transmissions. The robot controller was connected to the Arduino board through the communication interface RC232C. Figure 3 shows the three numerically controlled axes of the JEL robot and its kinematic structure.

### Figure 2. Arduino Uno board.

### Figure 3. 3D model of the JEL robot and its kinematic structure.

4. Development

ControlJEL is the software interface for programming and control of the JEL robot, developed during the research project. It is written using the Lua language and the Love2D framework. The purpose of the interface is to ensure system functionality, to create an accessible and easy to use tool for controlling the robot movement, to provide a programming environment for the robot and to act as a platform for developing offline programming and simulation capabilities. The interface is optimized
for usage on a touch-screen capable device. One of the main objectives taken into account when developing the interface was to be able to use a mobile device such as a smartphone or a tablet PC as a wireless teach-pendant, an approach that provided a greater level of flexibility to the system [5]. The software interface allows for both direct programming and programming by point-to-point teaching. The ControlJEL interface is shown in figure 4.

![ControlJEL software interface](image)

**Figure 4.** ControlJEL software interface.

ControlJEL can interact with the robot movement by receiving inputs from the user through the interface and converting these inputs to compatible instructions that are sent to the robot controller. The software interface of the ControlJEL program consist of the following modules:

- **Teaching**, which allows direct control of the robot movement both axis by axis and in polar or cartesian coordinates. This module also allows the recording of the target points that are used for robot trajectories. Also, this module displays the coordinates of the tool centre point both in cartesian and in polar coordinates, in real time.
- **Communication**, which allows checking the communication status with the robot, resetting the status and reinitializing the connexion.
- **Commands**, which allows sending specific commands directly to the robot controller.
- **PTP editor**, which is used for configuring the robot programs.
- **Module**, which is used for integrating additional modules, such as offline programming.

The ControlJEL interface has the following advantages:

- It is easy to use and does not require advanced programming knowledge, thus being suitable for the average robot user.
- Has a simple interface optimized for touchscreen.
- It has its own programming language developed specifically for this purpose, called Point-To-Point.
- It can connect to the V-REP environment for offline programming of the robot.
- It has a built-in programming by teaching module.

The main disadvantages of the ControlJEL interface are the following:

- It requires a Bluetooth or COM interface.
- The interface must run permanently during robot operation.
- Repetitive or conditional instructions such as FOR / IF are not available inside the built-in language but can be integrated through Lua command.

In order to acquire capabilities for programming the tool centre point position, the direct kinematic model has been calculated taking into account the three axes of the robot, as shown in equation (1),

\[
\text{Equation (1)}
\]
equation (2) and equation (3). In this development stage, the orientation of the end-effector (only influenced by the second axis) was not taken into account, the direct kinematic model only calculating the tool centre point position.

\[
x = T_e \cdot \cos \left( R_b \cdot \frac{\pi}{180} \right)
\]

(1)

\[
y = T_e \cdot \sin \left( R_b \cdot \frac{\pi}{180} \right)
\]

(2)

\[
z = T_z
\]

(3)

Where \( T_e \) represents the extension of the arm, \( R_b \) represents the rotation of the second axis and \( T_z \) represents the vertical translation of the column.

Point-To-Point is an accessible programming language with a simple syntax and real-time interpreter, developed specifically for this research. It has the purpose of robot program development, sequential recording and storage of the instructions that are used for trajectory configuration. It is a programming language based on BASIC, with a set of basic commands that can be directly configured through ControlJEL. The functionality of the Point-To-Point language can be extended by using the Lua language.

The offline programming and simulation of the JEL robot can be done using the V-REP environment by importing the specific parameters from the ControlJEL application, as shown in figure 5. In order to begin the simulation, it is required that the ControlJEL software interface be switched into the virtual mode and connected to the V-REP environment.

![Figure 5. The V-REP environment and the robot virtual model used for simulation.](image)
5. Conclusions

The research described in this paper had the purpose of creating an open-source, accessible and flexible platform for research in the field of wireless communication integrated with industrial robots. By developing the software interface, the opportunities of programming and control modules available on more accessible and mobile devices was explored. The system proved to be very flexible, being able to perform basic tasks in the fields of pick-and-place, drawing, sorting and manipulating, as well as certain sensors integration, such as artificial vision using cameras. Furthermore, the integration of various end-effectors was possible, such as electromagnets or vacuum grippers.

Future application development are oriented towards integrating a joystick type controller for robot manipulation, controlling the robot movements through the touchscreen using the virtual model and capabilities for teleoperating the robot through internet.

6. References

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