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Development of an industrial robot based automated assembly system

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Abstract: Nowadays, industrial robots are increasingly being used in all areas of human life. For each specific application, it requires students the knowledges of mechanical design, electrical engineering and motion programming. This paper presents the steps to build a model of an automated industrial robot that installs RAM modules on a mainboard of computer for educational purposes at the University of Transport Technology. The assembly system using a 6 degrees of freedom industrial robot with the type of KUKA KR6 R900-2 helps student to practice their thinking to design systems, self problem-solving skills.

Keywords: Industrial robot, product assembly, model for education, KUKA Sim Pro.

1. Introduction

The demand for human resources in the industrial sector is increasing. To train human resources who can work immediately after graduation, universities around the world, especially applied science-oriented schools, often associate theoretical teaching with practical training. The intuitively introduced training models not only help students easily understand the operating principles of the system, but also train logical thinking and system design thinking. In manufacturing plants, industrial robots are used quite commonly in automatic production lines. Industrial robots help to reduce human labor, replacing humans in performing simple operations that are repeated many times from palletizing, picking and placing to complex operations requiring high precision. There are many attractive ideas and possibilities to arrange a university lecture in the field of robotic engineering. Lukas Dusko used the industrial robot with 6 degrees of freedom with the type of KUKA KR6 R900 as the assistance robot for playing chess [1]. In this paper, the Sim Pro 2.2.2 software was used to design 3D-layouts of plant components and the vacuum cup with Venturi nozzle to pick up the pawns. Peter Poor and his colleagues introduced the collaborative robot model at Laboratory of Industry 4.0 at University of West Bohemia [2]. The FANUC CR-7iA collaborative robot has the function of positioning twenty colored metal cylinders on correct locations on the plate by the camera attached to the top of the gripper. Marilza Antunes de Lemos and colleagues introduced two robot models: Tic-tac-toe Opponent robot and Environmentalist robot [3]. The Tic-tac-toe robot uses competitive search techniques of Artificial Intelligences, computational vision, electronic and pneumatic devices to make decisions for a robotic agent on the Tic-tac-toe game. The second model consists of a game that contains a database of questions and answers about environmental themes. An algorithm selects the group of questions to be answered by the player, analyses the answers, and sends the results to an industrial robot that either congratulates or disapproves the player performance. Cokcan and Braumann introduced the application of industrial robots in teaching architecture students at the Technical University of Vienna [4]. Robots are used beyond the scope of CNC fabrication as open interfaces that confront students with problem-solving, geometry and programming. M. G. Aparicio et al. designed a robot prototype for students to learn some basic concepts of embedded systems and robotics [5]. Brunete et al. presented a new teaching method for robotics by which students can use a visual environment, called Hammer running on Android tablet to program and control industrial robots [6].

In this paper, the authors used the industrial robot with the type of KUKA KR6 R900-2 to design and build an automated robot model that installs RAM modules into the mainboard of the computer for educational purposes at the University of Transport Technology. The steps are as follows, respectively:

(1) Design of a suitable gripper for picking up/releasing the RAM modules.

(2) Simulation of an automated robot model that installs RAM modules on the mainboard of the computer with the software KUKA Sim Pro in version 3.1.

(3) Real time motion programming and test for the automated assembly robot model using smartPAD.

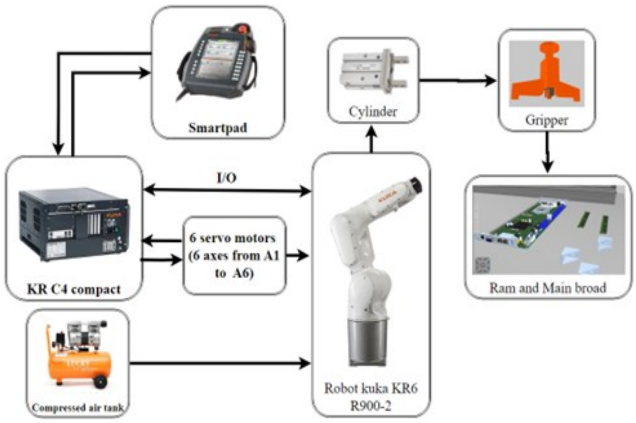
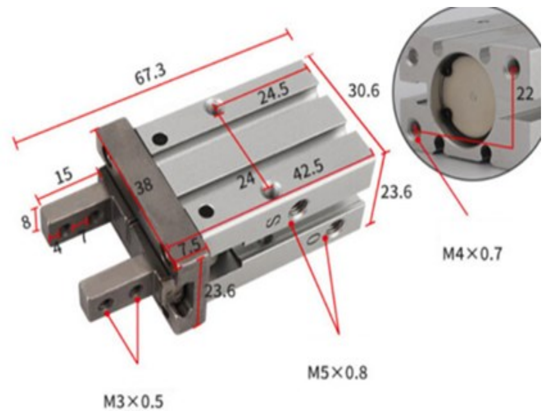


Figure 1. Block diagram of the designed model

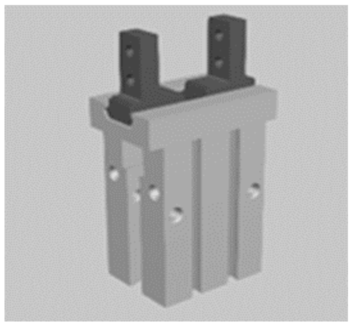
Figure 1 depicts the structural diagram of the proposed assembly robot model. The controller is a compact PC KR C4 that controls 6 servomotors corresponding to the 6 axes of the KUKA KR6 R900-2 robot. The model uses I/O ports of the robot to open and close the pneumatic cylinder that is designed to be placed into the gripper. Control commands can be entered through the smartPAD that is also connected to the compact PC KR C4 controller.

2. Design of a gripper

For the automated robot model that installs the RAM modules into the mainboard of the computer, the authors designed a specific gripper for picking up RAM modules by using the software KUKA Sim Pro 3.1. The gripper consists of a pneumatic cylinder with the type of MHZ2 – 16D for picking up/releasing RAM modules.



(a)



(b)

Figure 2. Pneumatic cylinder with the type of MHZ2 – 16D: a) Actual product, b) Simulated product in the software KUKA Sim Pro 3.1 [7]

The distance between two claws of the pneumatic cylinder with the type of MHZ2 – 16D is $20{,}9 \times 10^{-3}$ [m] in the open state and $14{,}9 \times 10^{-3}$ [m] in the close state. Because the RAM modules have a thickness of $1{,}3 \times 10^{-3}$ [m], the gap between two claws of the gripper needs to be reduced. Two small pieces as seen in Figure 3 were attached to the cylinder to clamp the RAM modules. The gap between two claws of the cylinder in the open state was designed to be equal to $3x10^{-3}$ [m] and in the close state equals to $1,4x10^{-3}$ [m].

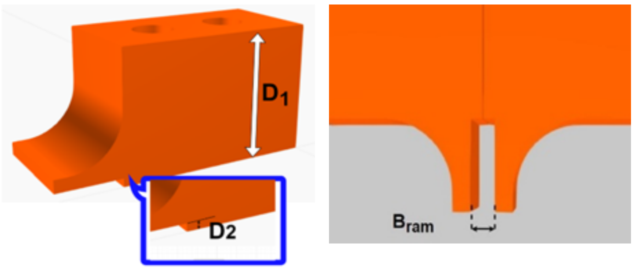


Figure 3. Additional pieces for clamping RAM modules

$$D_1 = \frac{A}{2} = \frac{20,9 \times 10^{-3}}{2} = 10,45 \times 10^{-3} \left[m\right]$$
$$D_2 = \frac{B_{RAM}}{2} = \frac{1,4 \times 10^{-3}}{2} = 0,7 \times 10^{-3} \left[m\right] \quad (1)$$

Where A is the gap between two claws of the cylinder in the open state.

B_{RAM} is the gap between two fingers after attaching two pieces.

Based on the dimensions of the cylinder, the robot wrist, the cover of the gripper and the connection with the robot wrist were designed as Figure 4.

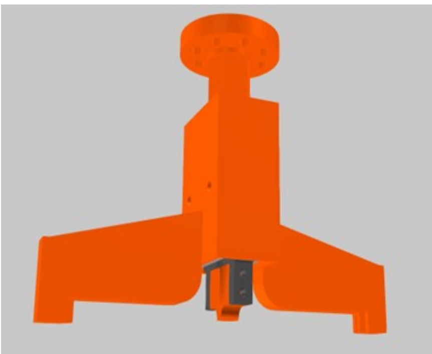


Figure 4. The designed gripper

3. Simulation in the software KUKA Sim Pro 3.1

After designing the gripper, the authors simulated kinematics of the system to evaluate the feasibility of the model.

Firstly, the gripper function of opening and closing were programmed and controlled by two outputs from the robot with number 10, 11 respectively (Figure 5). To pick up, hold the RAM modules from the case placed on the working table and install them into the mainboard of the computer, the motion planning was also programmed.

Every point in space is determined by 6 parameters (x, y, z) and (a, b, c), where (x, y, z) is the coordinate corresponding to the axes Ox, Oy, Oz with unit of mm and (a, b, c) is the orientation angles around the axes Oz, Oy, Oz with unit of degree Celsius. The industrial robot arm has a Tool coordinate and a Base coordinate where the origin of the Tool coordinate is chosen as the Tool Center Point (TCP) and the origin of the Base coordinate is chosen as one point on the working table.

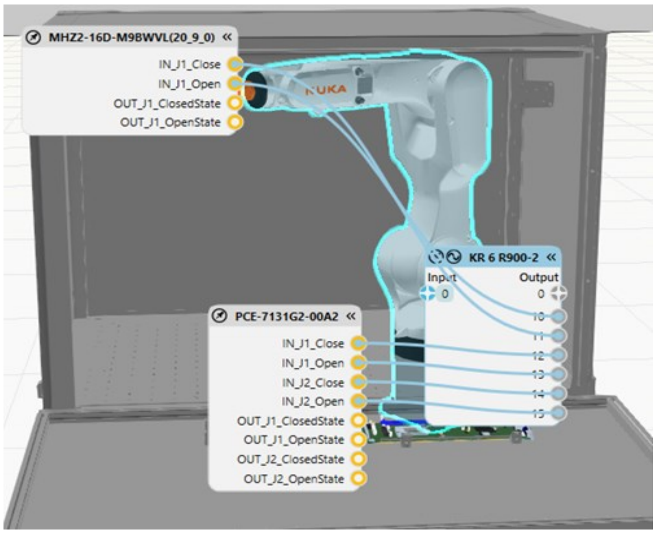


Figure 5. Wire connections between robot outputs and cylinder inputs

There are two programmed motion types for industrial robots: motion type Point-To-Point (PTP) and motion type Continuous Path (CP) [8]. In this application, we chose the movement of the robot heading to the point near the RAM modules placed on the base as PTP motion because the robot requires the shortest travelling time. When the TCP of the robot approaches the RAM modules, picks up them, and plugs the RAM into the mainboard, the selected motion type was LIN, one type of CP motion. The system simulation shows that it meets the requirements of the problem of the proposed model.

4. Test of the automated assembly robot model

Real time programming on industrial robots has a few differences compared to simulation programming with the software KUKA Sim Pro 3.1. The TCP was programmed according to the base coordinate of the working table. This helps when the table is moved, we just need to fix the origin of the base coordinate of the working table.

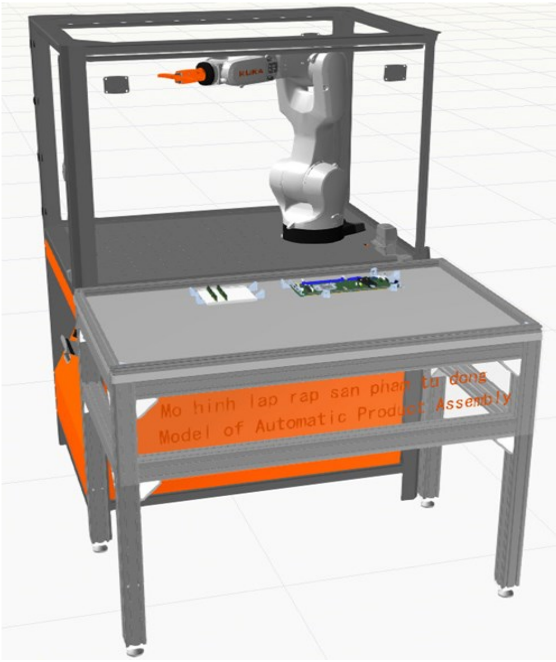


Figure 6. Model of the automated assembly robot

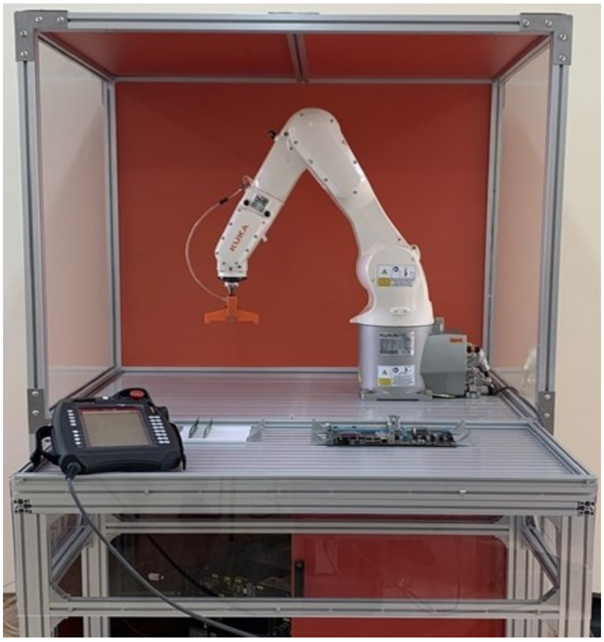


Figure 7. Real model of the automated assembly robot

Hence, the TCP of the robot still goes through all predefined points. During the tests, due to the wheels of the cage robot moves with the vibration which leads to unexpected error. To reduce this, the robot was programmed to move at 60 percent of the allowable maximum speed and small change in the angle of b to pick up exactly the RAM modules.

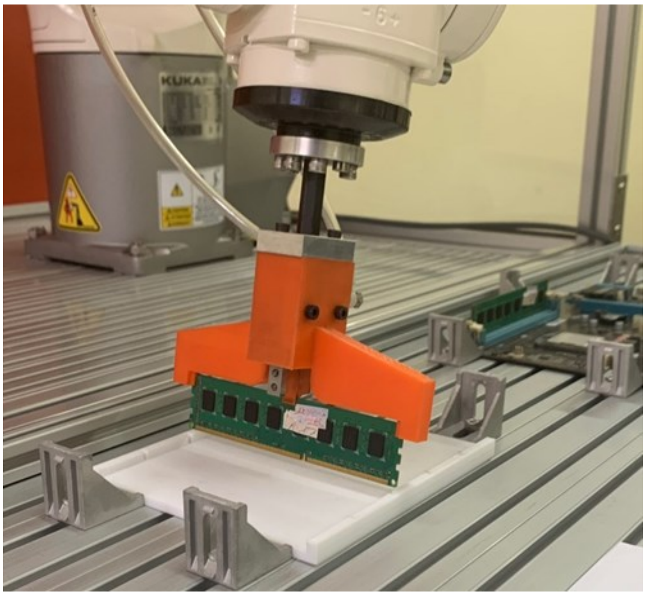


Figure 8. Tilt angle b of the gripper when picking up RAM modules

The designed model was tested with total of 100 times at different operating speeds less than 60 percent of the allowable maximum speed. The experimental results showed the system worked completely correctly. Because of the wheels of the robot cage, the robot should not move at the maximum allowable speed to prevent the damage. So, the duration time of the task is two times slower than its task in the simulation.

5. Conclusions

In this paper, the authors used the industrial robot 6 axes of KUKA KR6 R900-2 to design and build the automated assembly system that plugs the RAM modules into the mainboard of the computer. These steps were implemented: design of the specific gripper for picking up/releasing the RAM modules, simulation of the model motion with the software KUKA Sim Pro 3.1, and real time programming of the model using the smartPAD. The designed system is used for teaching at the University of Transport Technology, helping students apply the knowledge in practice and improving their design thinking and programming skills. The future work can be improved by fixing the force sensors at the tool of the robot to ensure safety when operating.

Acknowledgement

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