ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 6, Issue 3, pp: (1-12), Month: July - September 2018, Available at: www.researchpublish.com

Research for Industrial Robot Control by PLC Technology

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Abstract: **This thesis was commissioned for Hangzhou Dianzi University of computer science and technology with the aim of understanding the control system for a robotic. The main objective of this thesis was to understand a control system for the Robotic using a programmable logic controller (PLC). This report briefly describes robot technology and goes into more depth about where robots are used, and some of the anticipated social and economic impacts of their use .A number of short term transitional issues, including problems of potential displacement, are discussed. The ways in which robots may impact the economics of batch production are described. A framework for analyzing the impacts of robotics on economy wide economic growth and employment is presented. Human resource policy issues are discussed. A chronology of robotics technology is also given. In the industrial world, automation is one of the most important elements for development. It helps to reduce the need for humans and increase efficiency and productivity. The field of automation occupies large areas, mostly in industrial manufacturing and in addition to this; automation is applied to build a lot of sophisticated equipment which are used daily such as medical equipment (x-ray machines, radiography etc.), refrigerators, automobiles etc. Among all of these outcomes, the Robotic Arm is one of them, which is widely used in industrial proposes.**

Keywords: **robotic arm manipulator, PLC, motor controller, potentiometer.**

I. INTRODUCTION

What is the first thing that comes to mind when you think of a robot?

For many people it is a machine that imitates a human—like the androids in Star Wars, Terminator and Star Trek: The Next Generation. However much these robots capture our imagination, such robots still only inhabit Science Fiction. People still haven't been able to give a robot enough common sense to reliably interact with a dynamic world.

The type of robots that you will encounter most frequently are robots that do work that is too dangerous, boring, onerous, or just plain nasty. Most of the robots in the world are of this type. They can be found in auto, medical, manufacturing and space industries. In fact, there are over a million of these type of robots working for us today.

Some robots like the Mars Rover Sojourner and the upcoming Mars Exploration Rover, or the underwater robot Caribou help us learn about places that are too dangerous for us to go. While other types of robots are just plain fun for kids of all ages. Popular toys such as Teckno, Polly or AIBO ERS-220 seem to hit the store shelves every year around Christmas time.

But what exactly is a robot?

As strange as it might seem, there really is no standard definition for a robot. However, there are some essential characteristics that a robot must have and this might help you to decide what is and what is not a robot. It will also help you to decide what features you will need to build into a machine before it can count as a robot.

A robot has these essential characteristics:

- **Sensing:** first of all your robot would have to be able to sense his surroundings. It would do this in ways that are not similar to the way that you sense your surroundings. Giving your robot sensors: light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), and taste sensors (tongue) will give your robot awareness of his environment.

- **Movement:** a robot needs to be able to move around his environment. Whether rolling on wheels, walking on legs or propelling by thrusters a robot needs to be able to move.
- **Energy:** a robot needs to be able to power itself. A robot might be solar powered, electrically powered, battery powered. The way your robot gets his energy will depend on what your robot needs to do.
- **Intelligence:** a robot needs some kind of "smarts." This is where programming enters the pictures. The robot will have to have some ways to receive the program so that it knows what to do.

So what is a robot?

Well it is a system that contains sensors, control systems, manipulators, power supplies and software all working together to perform a task. Designing, building, programming and testing. a robot is a combination of physics, mechanical engineering, electrical engineering, structural engineering, mathematics and computing. In some cases biology, medicine, chemistry might also be involved. A study of robotics means that students are actively engaged with all of these disciplines in a deeply problem-posing problem-solving environment.

II. BACKGROUND OF THE THESIS

The topic of this thesis is chosen to understand robotics motion placed in Hangzhou Dianzi University of Computer Science and Technology Laboratory with the aim to get knowledge about the complete control system for a robotic . In this project, the control system refers to the development of a system which controls the automatic movements and accurate positioning of the robotic. During this process, a student is supposed to use his engineering knowledge.

This thesis includes various aspects of Mechanical Engineering; automations (control system), forms of electronic drives, general engineering subjects, parts design (strength of materials) and mathematics etc. The result is that this thesis also helps to develop the skills of practical knowledge about the subject matter in real life.

II.1 ROBOTIC LINKHOU:

The Robotic shown in Figure 2.1 below is from the Hangzhou Dianzi University laboratory. This Chinese robot has six axes which are driven by DC motors (24Vdc) and it is made to be controlled manually by using set of two potentiometers for each joint. To control a single joint, two potentiometers are used connected to each other in a feedback amplifier circuit. The comparator circuit compares the voltage between the axis potentiometer and the driver potentiometer, and it drives the motor in two directions depending on the voltage between these two potentiometers.

Figure 2.1: Robot Linkhou

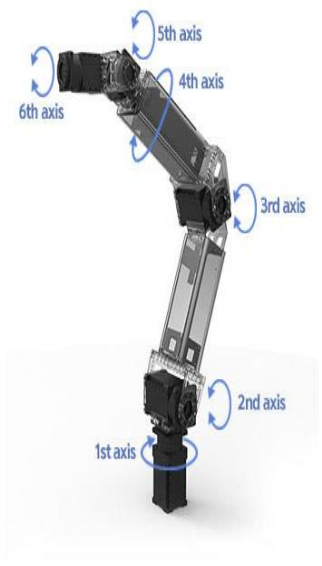


Figure 2.2: Robot structure

II.2 WORKING MECHANISM:

The output voltage for driving the motor depends upon the two potentiometers voltage value: the driving potentiometer and the axis potentiometer. Two potentiometers are integrated into the feedback amplifier circuit. The driving potentiometer voltage works like an input voltage and it can be set by the user whereas the axis potentiometer works like feedback voltage, altering the output. The axis potentiometer voltage depends upon the position of the axis and its changes due to the rotation of the axis. When the input voltage and feedback voltage are in the same phase, then the output becomes positive

and it drives the motors in a positive direction until the input voltage (driving potentiometer) and the feedback voltage (axis potentiometer) have the same voltage value. When the input voltage and feedback voltage are in the inverse phase, then the output becomes negative and it drives the motors in a negative direction until these voltages are the same. In every case, the direction of the motor is set in such a way that it rotates to change the voltage of the axis potentiometer the same as the driving potentiometer voltage and then the motor stops.

III. MAIN COMPONENTS

The component design requirement is set according to the need of this thesis. In this part, the main basic requirements are the process of the control system and the gripper design. Both of them have completely differents requirements which consist of the physical components and their features. On the basis of these features, the selection is made out of these components which meet the required criteria. For each component, a short introduction and products specification is given.

III.1 PROGRAMMABLE LOGICAL CONTROLLERS (PLC):

A programmable logic controller (PLC) is a type of digital computer that has an input and an output interface, controlled by a simulated program designed in a computer and it is used for automation for electromechanical process, typically for industrial use. In industry, PLCs are made to control the machinery of production lines. A PLC is designed for multiple input and output arrangements and these inputs and outputs are logically programmed in different forms, such as a ladder diagram, a structural text and a functional block diagram and stored in the PLC's memory. PLCs are reprogrammable and they can have monitors online to know the status of the operation. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a limited time, otherwise an unintended operation will result.

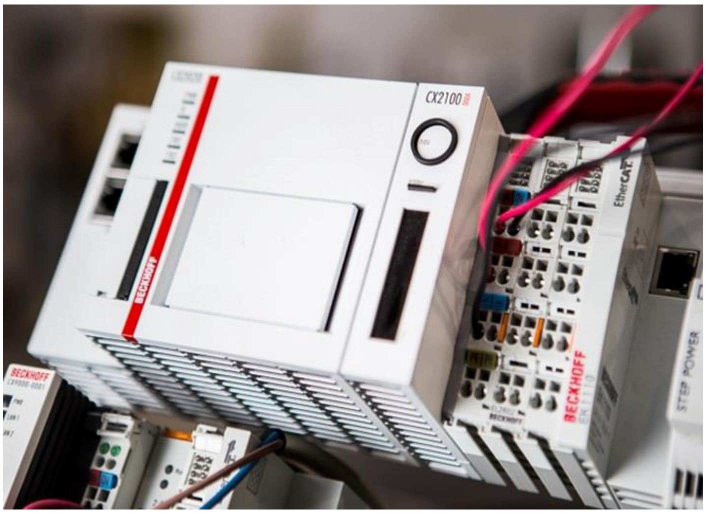


Figure 3.1.1: A typical PLC with one slot 16 inputs and and 2 sluts of 16 outputs

III.2 MOTOR CONTROLLER:

A motor controller is a device or a group of devices that serves to govern in some predetermined manner the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults.

A DC motor is an electric motor that runs on direct current (DC). A DC motor is used for driving the axis of the robot. The axis of the arm needs a larger amount of torque than the nominal torque which is supplied by the DC motor in its nominal speed. So, the torque of the motor is amplified with the help of a gear system which is embedded in the DC motor. The Figure below shows a Dayton DC Gear motor.

III.3 POTENTIOMETER:

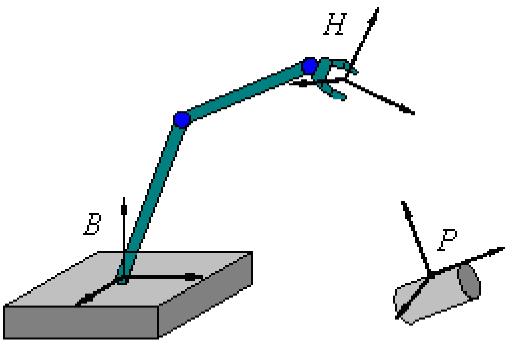
A typical single-turn potentiometer is shown in Figure 3.4 below. A potentiometer is a three terminal resistor with a sliding contact that forms an adjustable voltage divider for measuring the electric potential (voltage). It is commonly used in many electrical devices such as volume controls in audio equipment, position transducers, signal adjustment etc.

III.4 FUNCTIONAL DESCRIPTION:

A simple method for the movement of a Robotic Arm can be monitored and controlled by using a potentiometer. This system is built to control every joint movement manually. The shaft of a potentiometer is attached to the shoulder or elbow joint or motor. As the joint rotates, it turns the shaft of the potentiometer which changes the resistance; this change in resistance indicates the precise position of the joint. In our conditions, the Robotic Arm has all the rotating joints so the rotary potentiometers were for every joint. The rotary potentiometers have the limitation of angular freedom. Typically it has about a 0°-280° rotation angle which is sufficient to move the Robotic Arm all directions. Figure 4.1 below shows the positioning system using potentiometer.

IV. MATHEMATICAL BACKGROUND

Robotics: Using Transformation Matrices to Change from One Coordinate System to Another in Robotics



IV .1 Background:

In many robotics problems it is useful to define more than one coordinate system. For example in the picture to the right we have defined three coordinate systems. We have attached a coordinate system called *B* to the robot's base, another coordinate system called *H* to its hand and another called *P* to the piece that the robot must grasp. (By attached we mean that if we move the base, the hand or the piece then the corresponding coordinate system moves with it.) Coordinate system *P* is useful for locating points on the cylinder. Coordinate system *B* is useful for describing the location of the hand. And coordinate system *H* is useful for measuring distances from the hand.

Often we know the position and orientation of the piece *P* relative to the robot's base *B* but we need to know it relative to the hand *H* so that the hand can be moved correctly to pick up the piece. This can be computed if we know the position and orientation of the hand relative to the base. Note that orientation as well as position is important if we want the hand to be properly oriented to grasp the piece.

In this background section we will explain how a transformation matrix can be used to describe the location and orientation of a second coordinate system with respect to a first coordinate system.

Consider the following transformation matrix

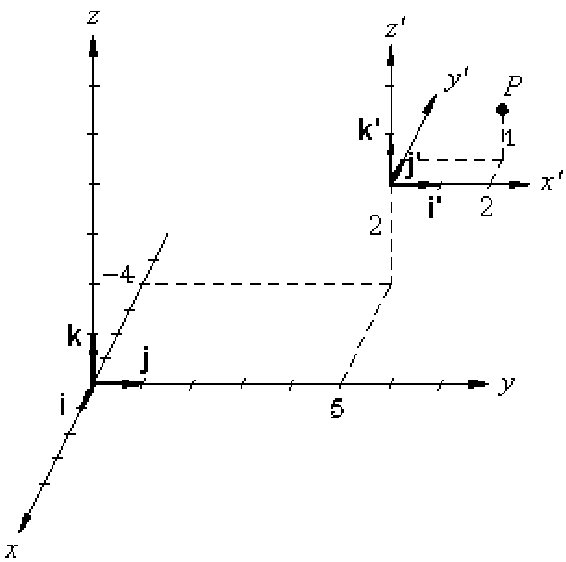
$$\left[\begin{array}{ccc|c} 0 & -1 & 0 & -4 \\ 1 & 0 & 0 & 5 \\ 0 & 0 & 1 & 2 \\ \hline 0 & 0 & 0 & 1 \end{array}\right] \left[\begin{array}{c|c|c|c} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ \hline 1 & 1 & 1 & 1 \end{array}\right] = \left[\begin{array}{c|c|c|c} -4 & -4 & -5 & -4 \\ 5 & 6 & 5 & 5 \\ 2 & 2 & 2 & 3 \\ \hline 1 & 1 & 1 & 1 \end{array}\right]$$

↑ transformation matrix; ↑ origin; ↑ unit vector **i**; ↑ unit vector **j**; ↑ unit vector **k**; ↑ origin; ↑ unit vector **i'**; ↑ unit vector **j'**; ↑ unit vector **k'**

T · {first coordinate system} = {second coordinate system}

$$\mathbf{T} = \left[\begin{array}{ccc|c} 0 & -1 & 0 & -4 \\ 1 & 0 & 0 & 5 \\ 0 & 0 & 1 & 2 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

Here is how this transformation matrix can be used to describe the location and orientation of a second coordinate system relative to a first coordinate system. We apply the transformation matrix to the origin and the endpoints of the unit vectors of the first coordinate system. This matrix multiplication produces the origin and the endpoints of the unit vectors of the second coordinate system:



These two coordinate systems are shown in the picture to the right. (The second coordinate system is the one with the tick marks.) Points can be located relative to either coordinate system. For example the point *P* is located at (*x'* = 2, *y'* = 1, *z'* = 1) in the second coordinate system and at (*x* = -5, *y* = 7, *z* = 3) in the first coordinate system.

Probably the quickest way to "design" a transformation matrix like

$$\mathbf{T} = \left[\begin{array}{ccc|c} 0 & -1 & 0 & -4 \\ 1 & 0 & 0 & 5 \\ 0 & 0 & 1 & 2 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

is to notice that the three columns of the 3x3 submatrix give the *orientation* of the second coordinate system in terms of the first like this:

$$\begin{array}{rl} \text{first column represents:} & \mathbf{i}' = 0\,\mathbf{i} + 1\,\mathbf{j} + 0\,\mathbf{k} \\ \text{second column represents:} & \mathbf{j}' = -1\,\mathbf{i} + 0\,\mathbf{j} + 0\,\mathbf{k} \\ \text{third column represents:} & \mathbf{k}' = 0\,\mathbf{i} + 0\,\mathbf{j} + 1\,\mathbf{k} \end{array}$$

and that the three element vector

$$\begin{bmatrix} -4 \\ 5 \\ 2 \end{bmatrix}$$

from the last column gives the *position of the origin* of the second coordinate system in terms of the origin of the first.

IV .2 Problem:

A robot's hand is supposed to pick up a part. A coordinate system, **P**, attached to the part is located relative to the "world" coordinate system, **W**, by the transformation matrix

$$^{W}\mathbf{T}_{P} = \left[\begin{array}{ccc|c} 0 & 1 & 0 & -1 \\ 0 & 0 & -1 & 2 \\ -1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

and the robot's base frame, **B**, is located relative to the world frame by

$$^{W}\mathbf{T}_{B} = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 9 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

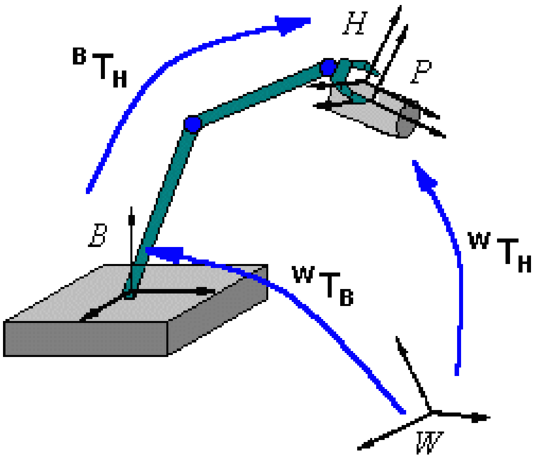
In order to put the hand on the part, we wish to align the hand frame, **H** and the part frame. What is the transformation matrix

$$^{B}\mathbf{T}_{H}$$

(giving the hand frame relative to the robot base frame) that makes this happen?

IV.3 Solution:

When the hand frame, **H**, and the part frame, **P**, are aligned then



$^{W}T_{H} = {}^{W}T_{P}$

This is shown in the diagram to the right. Now we use the fact that the transformation from the world to the base and the transformation from the base to the hand can be combined into a single transformation from the world to the hand, like this:

$^{W}T_{H} = {}^{W}T_{B}\,{}^{B}T_{H}$

Substituting in the known matrices we have:

$$\begin{bmatrix} 0 & 1 & 0 & -1 \\ 0 & 0 & -1 & 2 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times {}^{B}T_{H}$$

Solving this matrix equation for $^{B}T_{H}$ gives:

$$\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix}^{-1} \times \begin{bmatrix} 0 & 1 & 0 & -1 \\ 0 & 0 & -1 & 2 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = {}^{B}T_{H}$$

or:

$$\begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & -5 \\ 0 & 0 & 1 & -9 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & 1 & 0 & -1 \\ 0 & 0 & -1 & 2 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = {}^{B}T_{H}$$

or finally:

ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
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$$\left[\begin{array}{ccc|c} 0 & 1 & 0 & -2 \\ 0 & 0 & -1 & -3 \\ -1 & 0 & 0 & -9 \\ \hline 0 & 0 & 0 & 1 \end{array}\right] = {}^{B}T_{H}$$

As explained in the background, the three columns of the 3x3 submatrix give the *orientation* of the hand coordinate system in terms of the robot's base coordinate system and the last column gives the *origin* of the hand coordinate system in terms of the origin of the base coordinate system.

V. FIVE TYPES OF INDUSTRIAL ROBOTS AND HOW TO CHOOSE THE BEST FIT

In general, when people hear the word "robot" they immediately think of a piece of machinery that looks and acts like a human. In the world of plant operations, "robot" brings productivity and assembly to the mind of an operator. But even in this specific definition of the machinery, operators often refer to the types of robots in terms of their applications like handling robots, palletizing robots, packaging robots, etc.

A simpler, more complete definition of robotic types can be narrowed down to five types: Cartesian, Cylindrical, SCARA, 6-Axis and Delta. Each industrial robot type has specific elements that make them best-suited for different applications. The main differentiators among them are their speed, size and workspace. Knowledge of each operating aspect of all five types can help machine designers choose the best robot for their process.

Cartesian:

The most commonly used robot type for the majority of industrial applications is Cartesian. Plant operators often default to this type because they are easy to use and program. The linear movements of the Cartesian elements give the robot a cube-shaped workspace that fits best with pick-and place applications and can range from 100 millimeters to tens of meters. These robots are also a popular choice because they are highly customizable. Customers can determine the stroke lengths, speed and precision of the robots because most of the parts arrive separately and are assembled by the machine builders. That being said, one drawback to Cartesian robots is the complexity of assembly required. Overall, plant operators choose this robot design most often for the flexibility in their configuration that allows them to meet specific application needs.

Cylindrical:

Cylindrical robots are very simple and similar to Cartesian in their axis of motion. Most Cylindrical robots are made of two moving elements: rotary and linear actuators. Because they have a cylindrical work envelope, machine designers might select them for their economy of space. The robot can be placed in the middle of a workspace and, because of its rotation element, it can work anywhere around it. Simple applications where materials are picked up, rotated and then placed work best for Cylindrical robots. Installation and use are not complex, and they come as fairly complete solutions with minimal assembly.

SCARA:

SCARA robots offer a more complete solution than the Cartesian or Cylindrical. They are all-in-one robots, meaning a SCARA robot is equipped with x, y, z and rotary motion in one package that comes ready-to-go, apart from the end-of-arm tooling. The work envelope is similar to Cylindrical robots but it has more degrees of motion in a radius or arch-shaped space. Applications are also similar to Cylindrical and Cartesian robots, but SCARA robots can move quicker than the other two. They are seen often in biomed applications due to their small work area. Because SCARAs have the easiest integration they seem like the best solution for the majority of applications, but Cartesians are more common because of their level of customization.

Axis

Another all-in-one robot type is the 6-Axis. Though sometimes 6-Axis robots can be almost toy-sized, they are typically very large and used for large assembly jobs such as putting seats into a car on an assembly line. These robots operate like a human arm and can pick up materials and move them from one plane to another. An example of this would be picking a part up from a table top and putting it into a cupboard — something the other robot types cannot do easily. 6-Axis robots can move quick and come in complete solutions like SCARAs, however, their programming is more complicated. The robots can get so large and move so quickly that, if roller coaster seats were attached to them, they could simulate an amusement park ride. Because they are one of the largest of the five robot types, most designers choose them for their ability to make movements that others cannot to compensate for the loss of space.

Delta

As the fifth and final type, Delta robots are the fastest and most expensive. They have a unique, dome-shaped work envelope in which they can achieve very high speeds. Delta robots are best for fast pick-and-place or product transfer applications like moving parts from a conveyor belt and placing them in boxes or onto another conveyor belt. They also come as complete solutions for machine designers but are more complicated in use than the 6-Axis or SCARA robots. The main advantage of Delta robots is their speed and precision with which they operate.

VI. FUTURE TRENDS AND INVENTIONS

- In the Future, Robots Will Write News
- Artificial intelligence, robots and the future of work

A female robot waiter delivers meals for customers at robot-themed restaurant on in Yiwu, Zhejiang province of China.

- **U.S. Army Shows Off All Its Latest Robotic Experiments**

The U.S. Army held a demonstration day earlier this month, showing off the latest in military ground robots. The technology, which includes things like self-driving Humvees, is impressive but highlights a problem all of the services are facing: what exactly do you do with all of these robots?

The event, held at Fort Benning, Georgia , showed off a number of Army-funded robotic projects, including a robotic Humvee that acted as the vanguard for manned Humvees assigned to check out a suspected enemy position. According to defense News, a semi-autonomous Polaris MRZR all-terrain vehicle, equipped with a Hoverfly quadcopter drone, joined in the exercise. Once the position was identified, the Humvees engaged the target, with the Hoverfly confirming destruction of the target. A second location was scouted out by a ground drone that rolled out the back ramp of a M113 armored personnel carrier.

In another exercise, the human main gun-loader onboard a M1A2 Abrams main battle tank was replaced with a robotic autoloader, allowing him instead to control the MRZR robotic ATV. A second vehicle, the Automated Direct Indirect-fire Mortar artillery system, engages the enemy to pin it down while a third robotic vehicle, the M58 Wolf laid down a smokescreen to cover the pair of Abrams tanks as they moved into position to destroy the enemy.

What does the future hold for robotics ? It's hard to say, given the rapid pace of change in the field as well as in associated areas such as machine learning and artificial intelligence . But one thing seems certain: Robots will play an increasingly important role in business and life in general.

- **The future of robotics: 10 predictions for 2017 and beyond**

Research firm International Data Corp's (IDC) Manufacturing Insights Worldwide Commercial Robotics program recently unveiled its top 10 predictions for worldwide robotics for 2017 and beyond. The list has some interesting forecasts, and if they come true, they will likely have a significant impact on business and society.

"Technological development in artificial intelligence, computer vision, navigation, MEMS sensor, and semiconductor technologies continue to drive innovation in the capability, performance, autonomy, ease of use, and cost-effectiveness of industrial and service robots," said Jing Bing Zhang, research director of worldwide robotics at IDC Asia/Pacific.

"Robotics will continue to accelerate innovation, thus disrupting and changing the paradigm of business operations in many industries," Zhang said. IDC encourages companies to "embrace and assess how robotics can sharpen their company's competitive edge by improving quality, increasing operational productivity and agility, and enhancing experiences of all stakeholders," he said.

Zhang shared top predictions and major robotics trends that are set to present opportunities and challenges to organizations in 2017 and beyond:

1. Growth of "robot as a service. By 2019, 30 percent of commercial service robotic applications will be in the form of a robot-as-a-service (RaaS) business model. This will help cut costs for robot deployment.

2. Emergence of the chief robotics officer. By 2019, 30 percent of leading organizations will implement a chief robotics officer role and/or define a robotics-specific function within the business.

3. An evolving competitive landscape. By 2020, organizations will have a greater choice of vendors as new players enter the $80-billion information and communications technology market to support robotics deployment.

4. The coming robotics talent crunch. By 2020, robotics growth will accelerate the talent race, leaving 35 percent of robotics-related jobs vacant, while the average salary increases by at least 60 percent.

5. Robotics will face regulation. By 2019, government entities will begin implementing robotics-specific regulations to preserve jobs and to address concerns about security, safety, and privacy.

6. Rise of the software-defined robots. By 2020, 60 percent of robots will depend on cloud based software to define new skills, cognitive capabilities, and application programs, leading to the formation of a robotics cloud marketplace.

7. More collaborative robots. By 2018, 30 percent of all new robotic deployments will be smart collaborative robots that operate three times faster than today's robots and are safe for work around humans.

8. Arrival of the Intelligent RoboNet. By 2020, 40 percent of commercial robots will become connected to a mesh of shared intelligence, resulting in 200 percent improvement in overall robotic operational efficiency.

9. Growth in robots outside the factory. By 2019, 35 percent of leading organizations in logistics, health, utilities, and resources will explore the use of robots to automate operations.

10. Robotics for Ecommerce. By 2018, 45 percent of the 200 leading global ecommerce and omni-channel commerce companies will deploy robotics systems in their order fulfillment warehousing and delivery operations.

VII. CONCLUSION

Robot controllers have advanced to the point that they are a legitimate option for control of I/O. Robot controllers can be used in several different ways, providing tremendous system flexibility. it's most basic implementation, the robot can control I/O using commands written into the robot program. Or, the robot controller can be a ‘‘node’‘ serving the ‘‘master’‘ PLC. Or, given the advances in ladder editing, connectivity, processing speed, and additional I/O, the robot controller can serve the same functions as a small PLC. Eliminating an external PLC and using the robot controller for system level control functions is now a viable – and cost-effective -- alternative for many applications

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