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"Principals and applications of robotic control in motor vehicle manufacture"

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1 Introduction

Robotic control was first patented in 1954 by American inventor George Devol. Later, in 1959 this US patent was to form the basis of the world's first industrial robot, the Unimate. This first prototype Unimate #001 was installed in General Motors die cast plant in New Jersey with immediate success. With a great increase in production the road was paved for robots in factory automation. By 1961, the Unimate 1900 series was released to the market as the world's first mass produced robot for factory automation.

Nowadays robots are truly synonymous with the automotive industry. Car manufacturers are turning to robots as an automated process for spot, arc and laser welding, painting, assembly, die-casting and large part transfer. In 2015 over 50,000 robots were sold in Europe alone and it is expected that by 2017 the worldwide market value of robotics in industry will be worth over €25 billion.

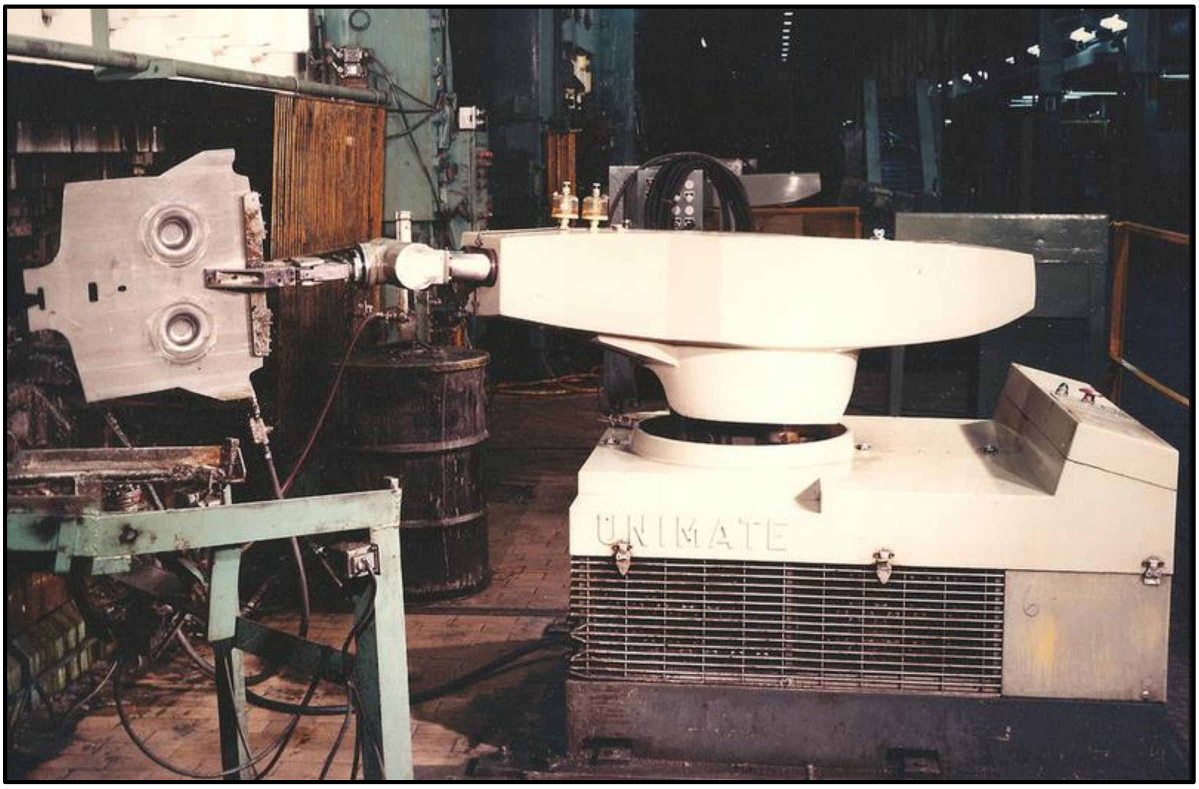

Figure 1 Unimate: Worlds first Industrial Robot www.nytimes.com

1.1 What is a robot?

A robot is a mechanical device that is capable of carrying out a series of actions automatically. They are designed to move materials, parts and tools and programmed to perform a variety of tasks in industrial automation. The industrial robot has become a standard component in factories due to their precision and high work output.

There are many different types of robots available today but they can generally be classified into two groups:

- Manipulators
- Teleoporators

1.2 Manipulators

Manipulators are pick and place style robots. They usually have clamps or pinchers mounted on the end of the robot arm that are controlled pneumatically or driven by small electric motors. The axes of the robot are the movable components on a robot arm. The complete robot arm, whether it has 4 axes or 6 axes is known as the manipulator section of the robot. The rest of the robot consists of a power supply and controllers.

Figure 2 Manipulator Robot www.turbosquid.com

1.3 Teleoperators

Teleoperators are commonly used in motor vehicle manufacture. These robots can be controlled by an operator to perform complex tasks. The operator can remotely access the robot and potentially perform the task on another continent. Teleoperators are also used for hazardous operations such as deep sea work in the oil and gas industry and handling of radioactive materials in nuclear power plants.

Figure 3 Teleoperator Robot www.mtbeurope.info

2 Principles of a Robot

2.1 Robot Axes

The example shown in Figure 4 is a typical 6 axes robot. These axes work in tandem to reach necessary targets. To achieve complete freedom of orientation and position a robot needs to have a minimum of 6 axis of movement. A 6 axis robot gives the programmer much more flexibility in controlling the robot. The motions of each of the axis are as follows:

- 1st Axis: Base twisting
- 2nd Axis: Base bowing
- 3rd Axis: Forearm flapping
- 4th Axis: Forearm twisting
- 5th Axis: Wrist flapping
- 6th Axis: Wrist twisting

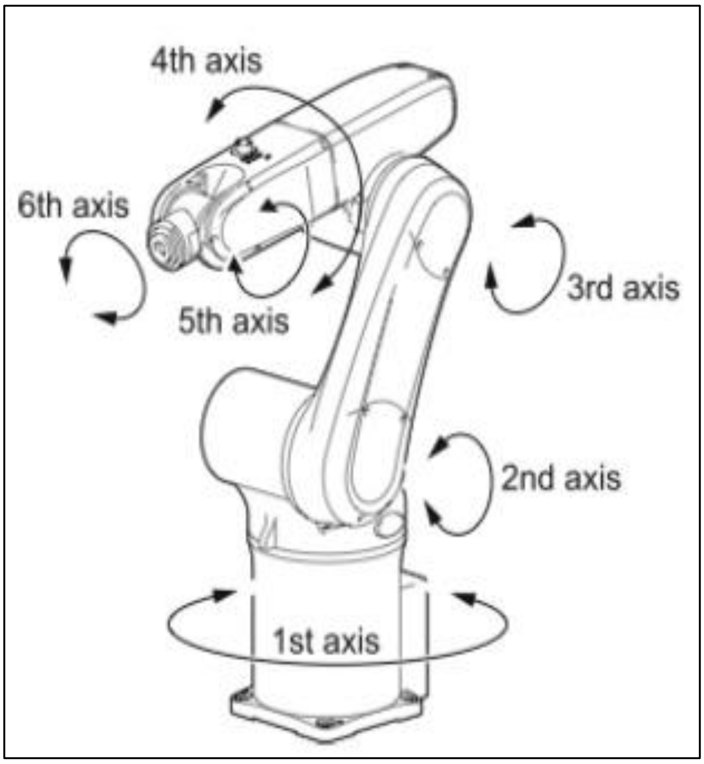

Figure 4 Robot Axes www.intorobotics.com

2.2 Mechanical Elements of Robots

Robot manufactures have developed many different configurations and mechanical designs of robots to enhance processes in industrial automation. Each configuration is suited for a very different style of job in motor vehicle manufacture.

These designs include:

- Articulated Arm Configuration
- Gantry Configuration
- SCARA Configuration

2.3 Articulated Arm Configuration

This design has multiple joints on arm members that have rotary movement, which gives the robot up to 6 axis of movement. This style of robot is ideal for precision tasks in the automotive industry such as welding, assembly and painting.

Figure 5 Articulated Arm Configuration

2.4 Gantry Configuration

The gantry configuration or Cartesian style of robot moves in 3 directions in translation of right angles to each other. These robots are generally extremely rigid and can carry heavy load with great precision. They are mainly used for moving large components such as engines and gearboxes throughout the production line.

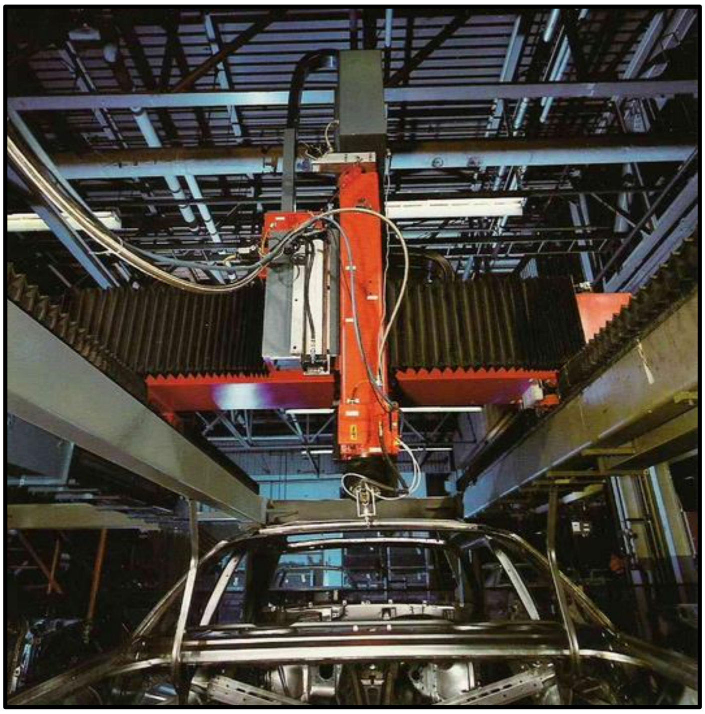

Figure 6 Gantry Configuration www.robohub.org

2.5 SCARA Configuration

Due to their high precision these robots are designed for detailed assembly tasks and pre drilling of mounting panels. They have a repeatability better than 0.025mm. Repeatability is the ability of a robot to return to the same position and is an important element of robotic performance.

Figure 7 SCARA Configuration www.abb.com

2.6 Working Envelope of Robots

The working envelope defines the points that can be reached by the robot and shows the exact movement of each axis and of a combination of axis. Besides the work envelope showing the limitations of the robot it is also there to avoid collisions with other robots or equipment on the process line. The programmer will teach the robot to avoid these possible collision areas by writing specific code into the programme to prevent the robot crashing.

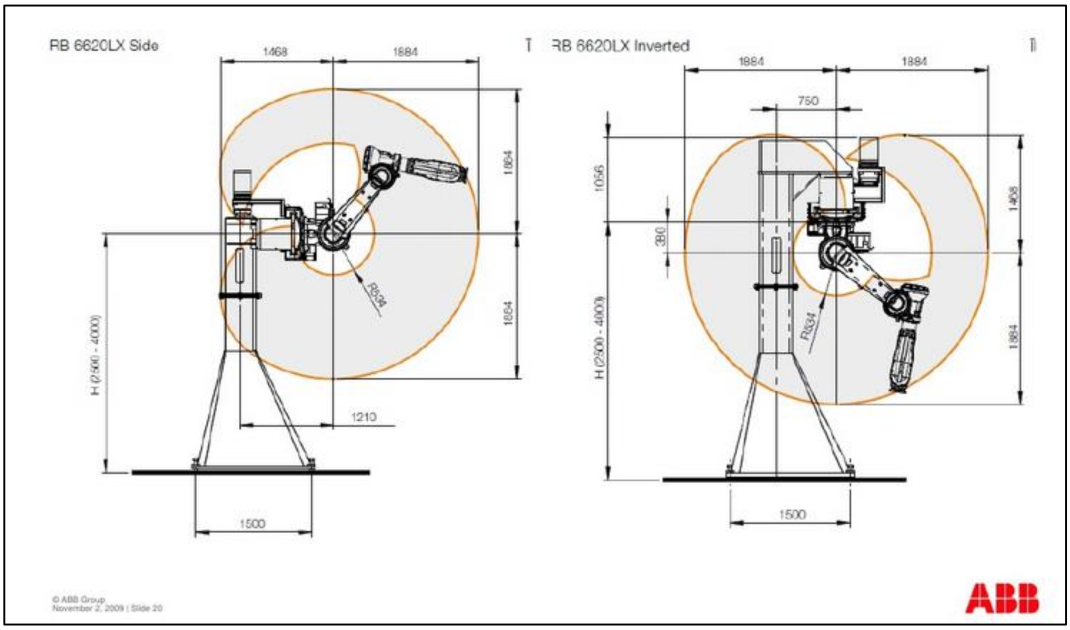

Figure 8 Working Envelope of Robots www.abb.com

3 Robot Drive Mechanisms

Most robots use AC motors to drive each of these axes due to their high torque and reduction in size compared to a DC motor. Added to this, the AC motor can be considered as maintenance free as it does not require brushes, is self-cooling and is completely enclosed.

Depending on the style of robot these motors would be connected to a variety of drive mechanisms including:

- Lead Screws
- Gear Drives
- Belt Drives

3.1 Lead Screws

Lead screws are generally used on one or more axes of gantry configuration robots. The main benefit of using this style of drive mechanism is its high precision.

3.2 Gear drives

It is not uncommon to have robot arms driven by a gear mechanism. They are mainly used in robots where precision isn't necessary. The main problem when using gears is backlash. Backlash occurs between mating gears and it is needed to keep the drive from locking up. Unfortunately gears have poor repeatability due to the accumulation of the small gaps between the teeth of mating gears.

3.3 Belt Drives

The most common drive mechanism on robots is belt drives. Belt drives use toothed belts, driven by pulleys to transmit energy for an AC motor to the robot arm. The have the advantage over lead screws and gear drives of lower costs and greater flexibility.

4 Robotic Control

Depending on the nature of work the robot has to perform the programming can be a relatively simple or a highly complex operation. Industrial robots can be taught movement patterns in three ways:

4.1 Lead by nose

The only way to get even layers when painting car panels is for an experience sprayer to physically guide the robot through the actions needed to perform the operation. These taught positions are then stored in the robots memory and played back to perform the task during production. This method of programming is also known as walk

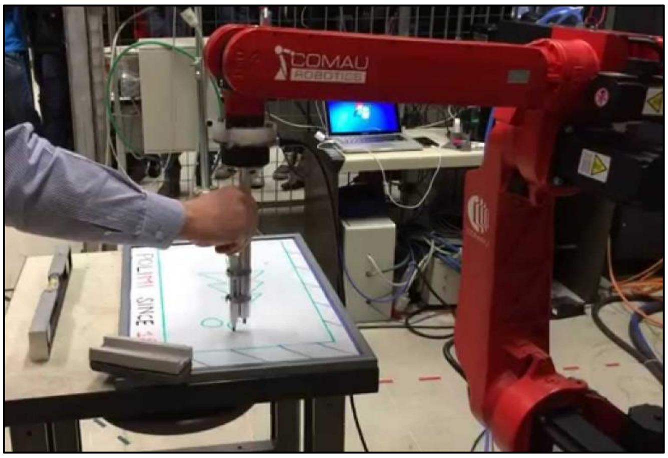

Figure 9 Lead by nose programming

4.2 Teach Pendant

The most common method of programming robots is via the teach pendant. The teach pendant either has push buttons or a joystick to control the robots movements. The programmer can move each axis of the robot to create the desired path needed for a specific operation. These paths can be repeated by replaying the sequence. Typically teach pendants are handheld devices and can either be wired or wireless.

Figure 10 Teach pendant programming

4.3 Off-line Programming

Off –line programming techniques use 3D software to graphically simulate the robots movements around a cell or manufacturing line. The main advantage of using this technique is that both the programmer and robot are not at risk of collision due to an operational error.

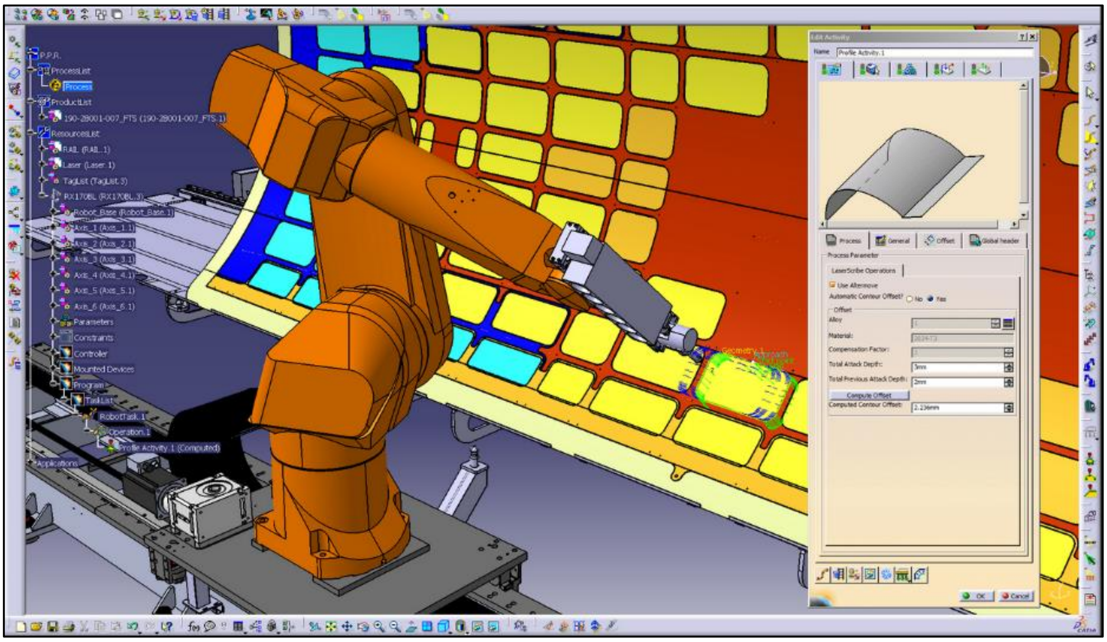

Figure 11 Off-line programming www.cenit.com

5 Robots in Motor Vehicle Manufacture

"Manufacturing is more than just putting parts together. It's coming up with ideas, testing principles and perfecting the engineering, as well as final assembly" James Dyson

5.1 Potential Benefits of Robots in Motor Vehicle Manufacture

The main benefit of implementing industrial robots is a reduction in the cost of labour to produce the finished product. In all motor vehicle manufacturing operations, added benefits such as energy savings, more efficient utilization of assets and warranty cost reduction may occur. Robots also offer untiring performance which saves valuable time. Their movements are always exact, so less material is wasted. These are, however, of significantly lesser magnitude than the labour cost savings.

5.2 People and Robots Working Together

Previously robots were enclosed by safety fences and guarding to keep the operator safe from potential collisions. Now, a new era of sensitive robotics has dawned allowing humans to work on complex tasks hand in hand with robots. The German company Kuka has released the first production robot that can safely work in collaboration with humans.

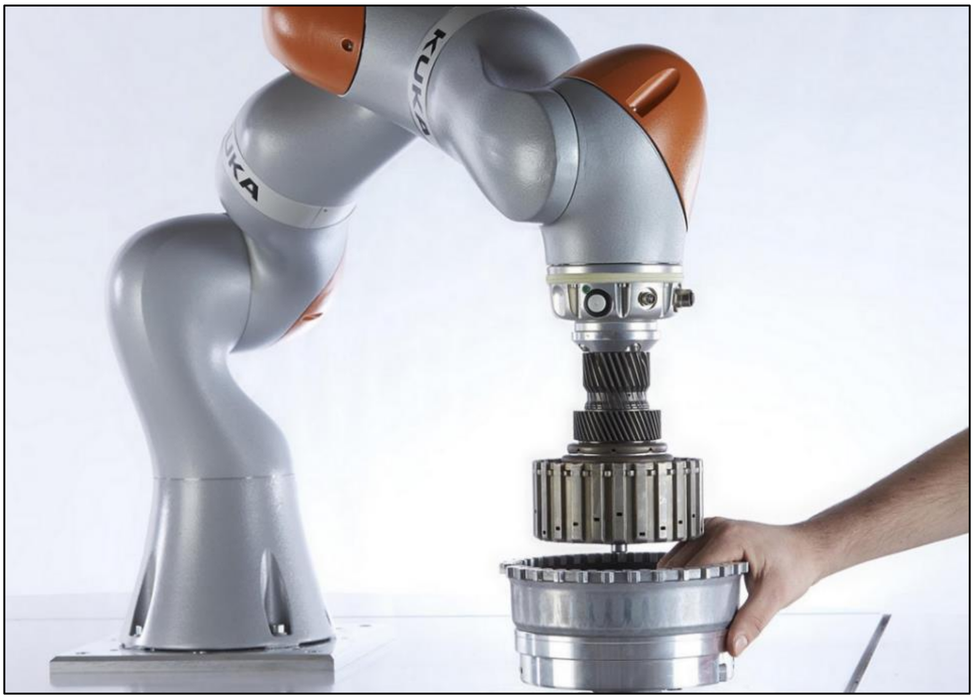

Figure 12 Robots and humans working together www.kuka.com

5.3 Robots in Industry 4.0

The fourth industrial revolution is on its way. Intelligent automation and robotics is fusing the digital world with the real world in what are becoming "smart factories". Smart factories will have more efficient manufacturing methods that saves resources. These factories can adapt to the production process in real time.

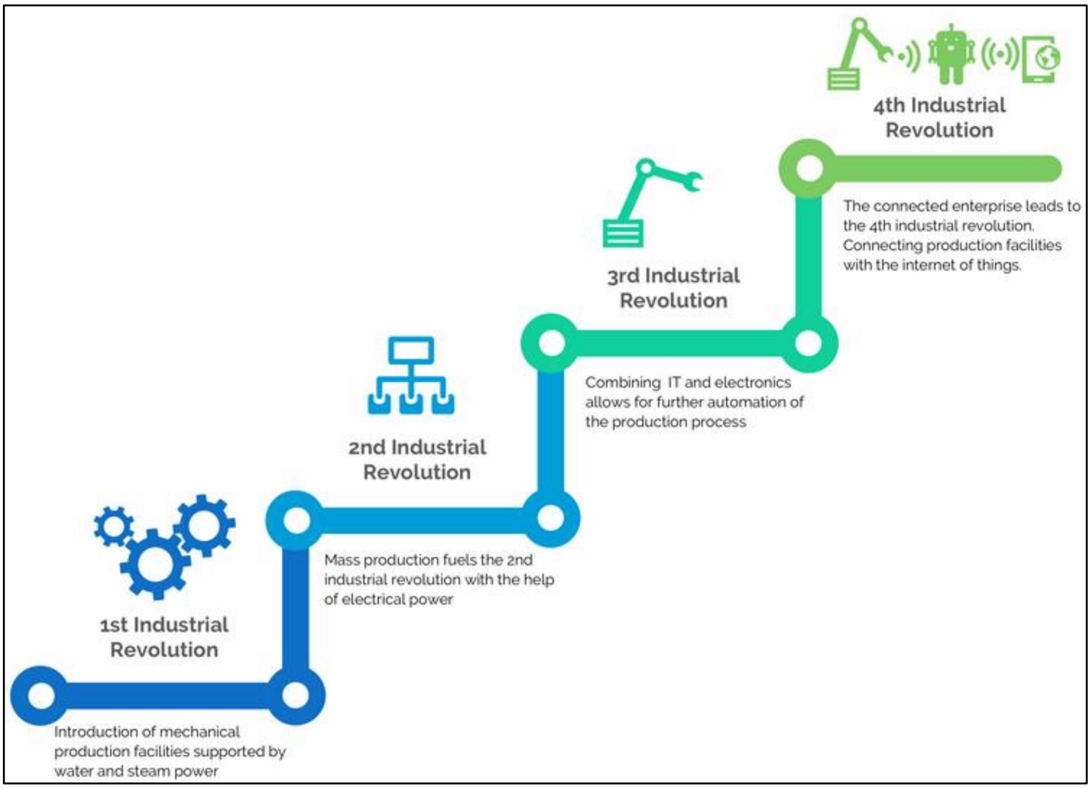

Figure 13 Industry 4.0 www.roboyo.de

6 Industrial Robots Summary

The Advantages of Industrial Robots

Quality:

Due to the high precision of robot's overall product quality can be greatly improved. Applications are performed with precision and high repeatability every time.

Production:

With robots, manufacturing efficiency is greatly increase, which directly impacts production. Robots don't need to go for lunch or take vacations so can greatly increase production compared to human operators.

Safety:

Workplace safety is greatly increased when humans are replaced by robots. Once the robot is programmed and guarded correctly accidents are extremely unlikely. Operators no longer have to work in hazardous environments and can take a supervisory role.

Savings:

The main savings when implementing robots on a manufacturing line is with labour costs. Robots cost far less the human operators and don't need health care or insurance packages.

Working with hazardous materials

The Disadvantages of Industrial Robots:

Expense:

Changing a production line from manual to automated has a high initial investment. Ongoing investment also occurs as robotics needs regular preventative maintenance checks.

Expertise:

Controls and software engineers are needed to initial programme the robot and keep it running to optimum condition.

Safety:

During maintenance intervals great care needs to be taken for humans in the vicinity of robots. Shutdown procedures need to be adhered by.

Loss of jobs for human operators

Keywords and Terminology

Manipulators

Teleoporators

Lead screw

SCARA Configuration

Lead-by-nose

Teach Pendant

Offline programming

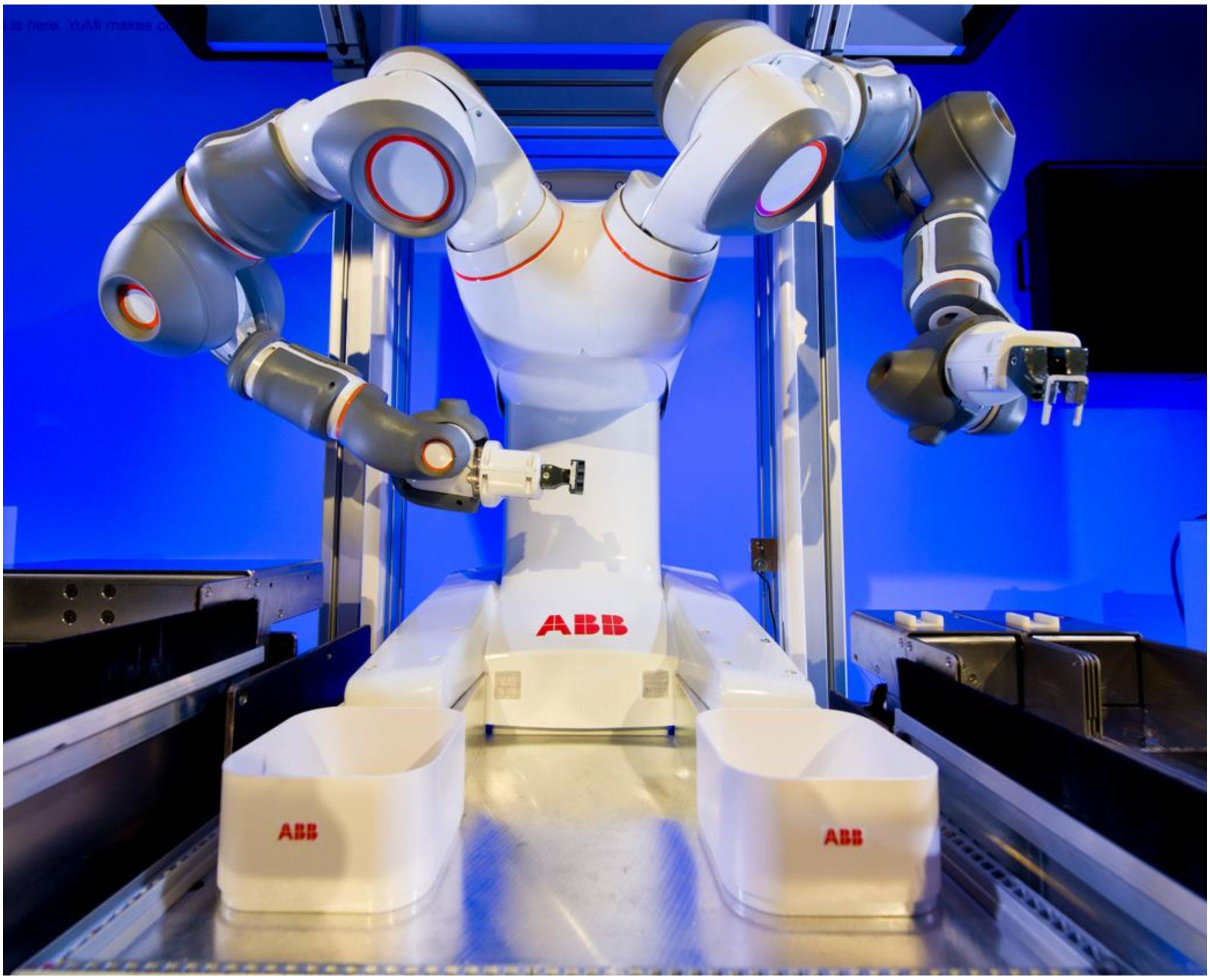

Figure 14 The Future www.abb.com