

Classification Of Robots and Industrial and Medical Applications

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Abstract. In the last 100 years, robots have evolved from fantasy to reality. Their design, research, and manufacture require the combination of various subjects such as CS, EEE, ME, AI, and others. The main objective is to replace humans in performing heavy or impossible tasks. Robots are classified into different categories based on their era and usefulness. This thesis will analyze industrial robots in terms of their basic stress conditions and activity scope with four degrees of freedom for the normal robot arm. The system architecture, various field interactions, and structure of mechanical fingers for human-like robot arms will also be analyzed. Additionally, this paper will examine the usefulness of service industry robots and highlight the exoskeleton robot for medical treatment by analyzing the forces, torques, and displacements during the walking of patients with lower limb disabilities. The interaction force between humans and exoskeleton robots will be calculated and a model will be constructed. Finally, some difficulties and possible solutions will be presented.

Keywords: Industrial robot, robot history, robot arm, exoskeleton robot, common infrastructure.

1. Introduction

The idea of designing and building tools to replace humans in work or daily life and reduce their burden dates back to ancient times. Such equipment appeared in several ancient civilizations, and some scholars named it "Automata," which means machines that show human-like forms. The term "robot" has a more general meaning [1].

The word "robot" first appeared in the 1920 novel "R.U.R.: Rossum's Universal Robots," written by the Czech writer Karel Čapek (1890-1938). He used the word "Robota," which means "forced labor" or "hard work." Before robots emerged in the true sense, they already existed in scientific fantasy and had the same appearance and intelligence as humans.

On the other hand, the famous "Three Laws of Robotics" and the term "Robotics" appeared in the novel "Runaround" by Isaac Asimov (1920-1992). These laws defined three rules for behavior and interaction between robots and humans.

As the robotics industry developed, robots became more visible in public, and literature about them gradually increased. Gasparetto put forward a historical outline describing the development of robots from ancient times until the Industrial Revolution [2].

2. Robot in different era

Robot could regard as next technological revolution and the evolution of industrial robot could be regard as four stages, as in [3]. Manipulators, robot with sensitized control, Industrial robot, and intelligent robot.

2.1. Manipulators

This is an early version of a robot that shows limited environmental information and only uses point-to-point control algorithms. To improve industrial production, automated machines were developed. Furthermore, numerical controlled (NC) machines that combine NC capable machining tools and manipulators laid the foundation for the emergence of robots. They were initially used to

solve high quotas in the automotive industry. These digitally controlled mechanical arms improved the efficiency of simple tasks like laying or picking.

2.2. Robot with Sensitized Control

This kind of robot shows some awareness of its environment. It has advanced sensory systems and can learn by demonstration. However, it has a large footprint.

The sensitized-control robot is based on sensor integration. It can produce different feedback in different environments. Most of them have various sensors to realize powerful ability. In addition, the Programmable Logic Controller (PLC) should be highlighted in the industrial environment. PLC has become a normal device as it is simple to program and is adapted for the control of manufacturing processes [4]. It first appeared in the automotive industry.

2.3. Industrial Robot

These kinds of robots have computers as dedicated controllers and can be controlled by new programming languages, making them re-programmable. Some of them combine sensors and have the ability to produce different feedback in different environments.

The industrial robot is closer to the robot that most people think of. Therefore, they believe that robots were born during the industrial robot era. During this time, robots were being used in various industrial sectors as they could perform more automatic tasks like welding and spraying instead of simple tasks like laying, picking, or responding.

After that, key technologies for robots appeared. In 1980, Internet access [5] became available, and in 1983, Ethernet became the standard [6]. In 1991, the Linux kernel was announced [7], and soon after, real-time patches appeared [8,9]. Linux-based systems have powerful determinism, and robots started to be used outside of the industrial environment.

2.4. Intelligent Robot

This kind of robot shows advanced computing capabilities and more sophisticated sensors, allowing for more reliable information to be sent to the controller for analysis. These robots can carry out logical reasoning, solve problems, and learn from their environment. Additionally, collaborative robots have been introduced, which are safe enough to work alongside human workers in the same environment, thus improving production efficiency.

2.5. Current Development of Robots

Industrial robots have shown significant improvements in accuracy, speed, and load capacity, but have experienced a slowdown in innovation compared to previous decades.

With the widespread adoption of Artificial Intelligence, neural networks (a subset of AI) have gained popularity. The increase in datasets has led to remarkable advancements in computer vision and machine translation [10, 11].

3. Different using of robot in various industry

Robots are categorized based on their purpose into three categories, namely, industrial engineering, service industry, and special type robots. This section aims to highlight the role of numerical control systems in industrial robots and the development of robots in the medical science field.

3.1. Industrial Engineering Robot

This kind of robot mainly involves two fields: mechanical arm and Automated Guided Vehicle (AGV).

Robot arms can be classified from various dimensions, such as application fields: welding, spraying, 3C, etc. They can also be divided according to the number of joints or structure. In addition, there are currently two special branches from the technical route: collaborative robotic arms, which

have features like teaching by demonstration, high safety, etc. Another one is two-armed robots that can work together.

AGVs can be used for both industrial and non-industrial purposes, but most of them are still considered in the industrial field. Heavy-duty AGVs are generally considered within the field of industrial robots.

3.1.1 Normal Robot Arms

The links of robot arms are connected with rotational joints to form a kinematic chain. The end of robot arms is called the end-of-arm-tooling or end effector, which functions similarly to a human hand and provides more flexibility. This part has powerful adaptability and can be designed as an independent part or even using finished products for economic and efficient purposes. Fig. 1 shows the free body diagram of the robot arm (excluding the end effector).

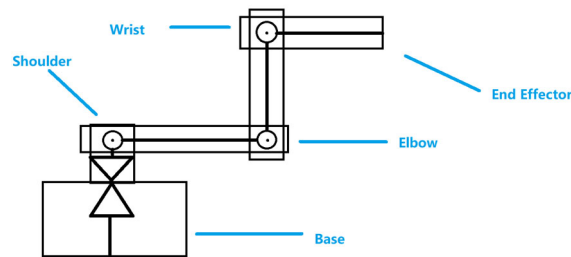


Fig. 1 Free body diagram of the robot arm

A simple robot arm typically has at least four degrees of freedom, which is also the most common type. It can achieve movements in about half of the spherical field and can satisfy most necessary movements. Servo motors are often used in robot arms because of the encoders inside, which provide feedback and allow for automatic adjustments. However, one disadvantage is that the arm can only rotate less than 180 degrees, which limits its range of motion [12]. Fig. 2 and Fig. 3 show the force analysis of the largest loads in a series [13].

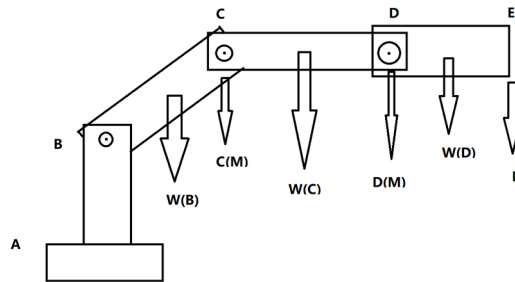


Fig. 2 Force analysis in whole robot arm

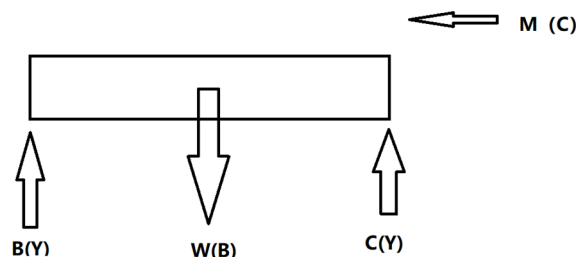


Fig. 3 Force analysis in single component

3.1.2 Human-Liked Robot Arms

As the number of robot arms increases, they are being designed to imitate human activities. For example, a group of USA engineers developed an eight degrees of freedom robot arm that can imitate the human hand in picking up and holding objects of various shapes [14].

A relatively mature technology that imitates human tendons for pushing and pulling activities is based on a small motor as the actuator, along with a strong gearbox and plastic coil. This technology uses a specialized linkage system to achieve human-like activities, as shown in Fig. 4. With a series of three joints, the robot arms can perform almost all the movements that humans can [14].

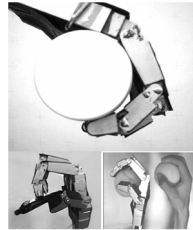


Fig. 4 Robotic hand grasping different objects [14]

This project demonstrates the development of a complete mechatronic system by integrating research findings from different fields and fostering interdisciplinary collaboration between mechanical, electronic, and software development. This approach is more effective than developing each area independently, as it enables better interaction and coordination between the different components. Fig. 5 illustrates this integrated approach.

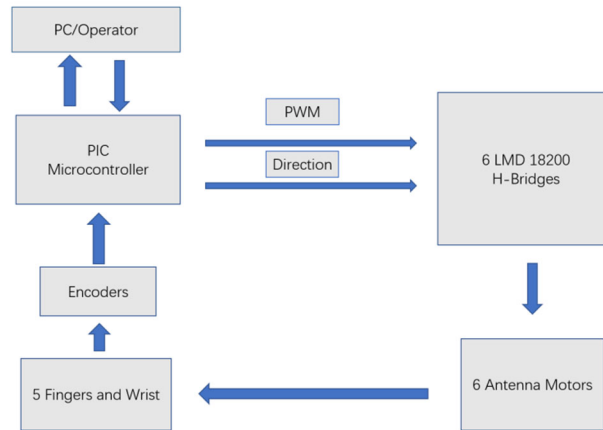


Fig. 5 System architecture

This project based on trajectory formula, control circuit, mechanical design manufacture, software development, and actuator and sensing development for motion control. The assembly unit and specification shows in Table.1.

Tab. 1 Assembly unit and specification

Number of fingers	5
Degrees of freedom	8 (1 for each finger)
Current sensors	6 (integrated in LMD18200)
Actuators	9 (12VDC)
Finger length	135mm (from first axis to fingertip)
Finger width	15mm
Hand length	260mm (from first axis to fingertip)
Maximum load	2 N (at fingertip)
Maximum Cable Length	700 mm (from motor to finger)

This kind of robot arm using frames for human hand's bone and linkage for tendon. Based on kinematics for overall arrangement of joints, linkages, and frames, which achieve more suitable and efficient movements, and avoid the disturb in between different parts shows in Fig. 6.

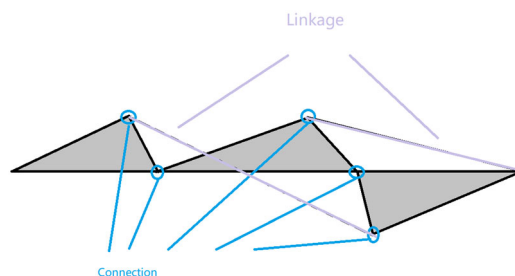


Fig. 6 Structure diagram of mechanical finger

3.2. Service Industry Robot

A service robot is a robot that operates semi or fully autonomously to perform services useful for the well-being of humans and equipment, excluding manufacturing operations [15].

The coverage is broad and basically covers all types of robots in non-industrial, manned environments.

Logistics: Food delivery, express delivery, drug delivery (hospital logistics), etc., can be considered AGV versions in non-industrial environments. However, due to the large number of mobile personnel in non-industrial scenarios and the complex terrain (the factory usually has a flat ground, which is not necessarily the case in ordinary environments), there are still many special technologies.

Interaction: The most common manifestation of robots that primarily interact with people is the welcome robot, which provides active information services (i.e., can proactively come to people to provide information) and guidance services (lead the way) through a combination of voice and screen+wheeled chassis. There are also interactive robots for household use, such as educational robots. In addition, there are very few bipedal walkers, but if divided by purpose, most of them are still interactive.

Security monitoring and patrolling: usually composed of wheeled sites+detection equipment, such as surveillance cameras, thermal infrared, and so on. The main logic is patrolling. For example, you can regularly patrol the equipment of a certain substation to see if there is a problem, patrol a large area of the factory to confirm various abnormalities, and so on.

Medical treatment: Although medical robots are a relatively small market segment in robotics applications, as the service robot with the highest unit value, medical robots have become a hot spot for development and investment in the current robotics and medical industry. According to the International Federation of Robotics (IFR) classification, medical robots can be divided into four categories: surgical robots, rehabilitation robots, auxiliary robots, and service robots.

As the technology and concept of robots that directly contact human bodies have become mature, the need for exoskeleton robots has increased sharply. Robots that used to work in factories only are now gradually connecting with the human body, providing muscle power, speed, or assisting patients in recovery. Exoskeletons can be divided into rigid and soft types, each showing obvious advantages and disadvantages corresponding to different uses [16].

Most patients with lower limb paralysis are not able to resume normal gait trajectory, but a method based on PBF neural network to control adaptive sliding mode was developed, and a tactics for autonomous adaptation robot interactive force was put forward.

Human walking tends to be divided into four phases, and every phase requires different force from the exoskeleton for thighs and calves, as shown in Fig. 7. Their movements are also worth analysing.

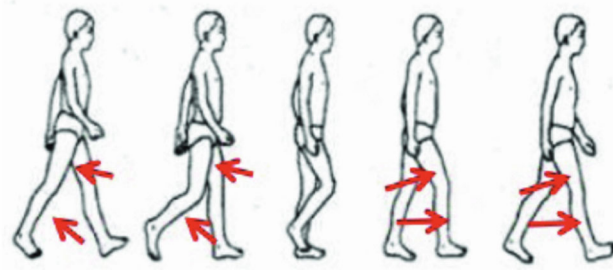


Fig. 7 Force analysis on the leg (walking)

Table 2 shows man-machine interaction model related data. Path through the formula (1) the torque required is easily to calculate, and force sensors can measure the interaction force $T(e)$.

Tab. 2 Force and Torque

Force and Torque	
Interaction force (exoskeleton and legs)	$T(e)$
torque required (normal walking)	$T(q)$
residual torque (inside patients' legs)	$T(h)$
gravity of the leg	G

$$T(q) = T(h) + T(e) + G \tag{1}$$

The interaction could be transformed to the impedance model as Fig. 8. Table 3 shows the explanation of character.

Tab. 3 Force, Torque and Displacements

Force, Torque and displacements	
Motor output torque (actual)	$T(\text{motor})$
Interaction force (exoskeleton and legs)	$T(\text{int})$
gravity of the leg	G
exoskeleton robot displacements	$\Theta(\text{exo})$
wearer's leg displacements	$\Theta(\text{h})$

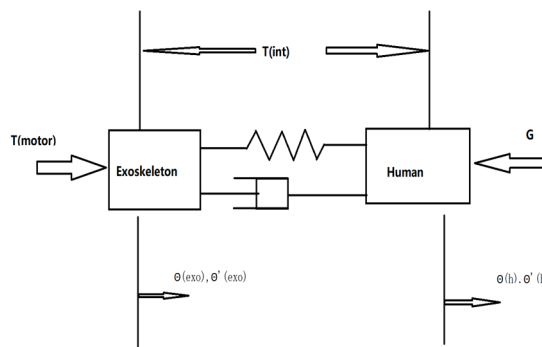


Fig. 8 Interaction model of human and exoskeleton

3.3. Special Type Robot

This robot is designed for a specific field and purpose. The main reason for treating it as a single part is that the basic structure and technical approach of both industrial and service robots are often developed by following a few basic schemes, whereas special purpose robots can vary greatly, especially in terms of their structure, which is often designed for a specific scenario with low versatility.

4. Future development and problems

Nowadays, the components of robots often do not match with each other, and the only solution to this problem is to create a common infrastructure. For example, common electrical and logical interfaces [3]. Sony's AIBO and LEGO's Mindstorms have already implemented this technology, as their robots are able to switch components easily by using common infrastructures [17,18].

Robots were considered the first machines in the history of inventions that were able to communicate with humans, and people wished for them to have a friendly appearance and natural motions. Therefore, the humanoid robot became the ideal robot in the imagination of most people. Unfortunately, some animation designers or industrial designers who are not familiar with the inside structure of robots tend to design drafts that are not physically feasible, requiring significant modification. Therefore, it is important to cultivate "Robot Designers" or "Robot Creators," as there is still much room for development in the robotics industry [19].

5. Conclusion

There are various standards used to classify robots, but two primary categories are industrial engineering robots and service industry robots. Among them, robot arms and exoskeleton robots are among the most popular. Normal robot arms are suitable for industrial manufacturing, while humanoid robot arms provide the basis for humanoid robots and exoskeleton robots. As robot technology continues to develop, there is an increasing demand for robots that are not only visually appealing and useful, but also smarter, lighter, and more powerful. It is likely that we will see a wide range of robots in our daily lives in the near future, taking on various forms and serving a variety of purposes.

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