Evolution of   Robotics

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ABSTRACT

This article surveys traditional research topics in industrial robotics and mobile robotics and then expands on new trends in robotics research that focus more on the interaction between human and robot. The new trends in robotics research have been denominated service robotics because of their general goal of getting robots closer to human social needs, and this article surveys research on service robotics such as medical robotics, rehabilitation robotics, underwater robotics, field robotics, construction robotics and humanoid robotics. The aim of this article is to provide an overview of the evolution of research topics in robotics from classical motion control for industrial robots to modern intelligent control techniques and social learning paradigms, among other aspects

The word robot was first mentioned in a fictional play by Karel Čapek, a Czech writer. The story of play revolved around a company called Rossum's Universal Robots, which was depicted to have gained immense popularity after starting to manufacture workers (a.k.a. robots) in large numbers. These so-called workers did everything that humans preferred not to do while all they lacked was emotions.

Since that imagination until now, we have come a long way to the age of AI-infused autonomous machines where robots are being granted citizenships and digital human is also a thing. While recalling that robots were initially supposed to be doing only labour-intensive mindless jobs, here is a sneak peek into the exciting journey that this technology has taken

Keywords:

Field robots, humanoid robots, industrial robots, medical robots, mobile robots, rehabilitation robots, robtoics, servicerobots, underwater robots, walking robotsservice robots.

1. INTRODUCTION

During the last 45 years, robotics research has been aimed at finding solutions to the technical necessities of applied robotics. The evolution of application fields and their sophistication have influenced research topics in the robotics community. This evolution has been dominated by human necessities. In the early 1960s, the industrial revolution put industrial robots in the factory to release the human operator from risky and harmful tasks. The later incorporation of industrial robots into other types of production processes added new requirements that called for more flexibility and intelligence in industrial robots. Currently, the creation of new needs and markets outside the traditional manufacturing robotic market (i.e., cleaning, demining, construction, shipbuilding, agriculture) and the aging world we live in is demanding field and service robots to attend to the new market and to human social needs. This article is aimed at surveying the evolution of robotics and tracing out the most representative lines of research that are strongly related to real-world robotics applications robots. Currently, the creation of new needs and markets outside the traditional manufacturing robotic market (i.e., cleaning, demining, construction, shipbuilding, agriculture) and the aging world we live in is demanding field and service robots to attend to the new market and to human social needs. This article is aimed at surveying the evolution of robotics and tracing out the most representative lines of research that are strongly related to real-world robotics applications.This article addresses the evolution of robotics research in three different areas: robot manipulators, mobile robots, and biologically inspired robots. Although these three areas share some research topics, they differ significantly in most research topics and in their application fields. For this reason, they have been treated separately in this survey. The section on robot manipulators includes research on industrial robots, medical robots and rehabilitation robots, and briefly surveys other service applications such as refueling, picking and palletizing. When surveying the research in mobile robots we consider terrestrial and underwater vehicles. Aerial vehicles are less widespread and for this reason have not been considered. Biologically inspired robots include mainly walking robots and humanoid robots; however, some other biologically inspired underwater systems are briefly mentioned. In spite of the differences between robot manipulators, mobile robots and biologically inspired robots, the three research areas converge in their current and future intended use: field and service robotics. With the modernization of the First World, new services are being demanded that are shifting how we think of robots from the industrial viewpoint to the social and personal viewpoint. Society demands new robots designed to assist and serve the human being, and this harks back to the first origins of the concept of the robot, as transmitted by science fiction since the early 1920s: the robot as a human servant. Also, the creation of new needs and markets outside the traditional market of manufacturing robotics leads to a new concept of robot. A new sector is therefore arising from robotics, a sector with a great future giving service to the human being. Traditional industrial robots and mobile robots are being modified to address this new market. Research has evolved to find solutions to the technical necessities of each stage in the development of service robots.

2. Historic Times

2.1 Emergence of Robotics

The industrial revolution paved the way for new advances in the area of science and technology. This was also the time when "robotics" was established as a study of science and usage of robots. In an attempt to prevent an anticipated misuse of robots in a rapidly increasing automation industry, science fiction writer Isaac Asimov drafted the following famous "Laws of Robotics":

Law One: A robot may not injure a human being, or, through inaction, allow a being to come to harm.

Law Two: A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law.

Law Three: A robot must protect its own existence as long as such protection does not conflict with a higher order law.

To showcase the necessity of such laws, Asimov went on to write about three fictional stories in which robots brought the end of humanity. He hoped to see a world where these human-like robots would act only as our servants- henceforth, proposing a mandatory set of programming rules to prevent them from causing any harm to humans.

2.2 The World of Today

Technology is all set to make us, not only physically, but also emotionally dependent on robots. An example of this is Yotaro, a baby robot built with the sole aim to encourage young couples in Japan to become parents. It lets you experience the "real sense" of physical contact as with a real baby and supposed to trigger similar emotions.

On touching its soft and warm face or stomach, Yotaro sets off to show a variety of different reactions like smiling, crying (with tears), sleeping, sneezing, and expressing anger. The exact reaction chosen depends on the sense of touch that it experienced and interpreted. An intelligent emotion control program handles the change of expressions- for example, when its nose is touched, Yotaro sneezes; when its cheeks are touched, it becomes happy and so on. It can even simulate a running nose

Technological singularity is said to be that hypothetical point in time at which machines grow up to be so intelligent that it is no longer possible to differentiate between them and humans. Scary as it may sound, we must also remember that humans evolved until this point by forcing other species into an existential crisis- maybe it's time to pay back!

2.3 The History of Robotics

Robotics is a field that deals with creating humanoid machines that can behave like humans and perform some actions like human beings. Now, robots can act like humans in certain situations but can they think like humans as well? This is where artificial intelligence comes in! AI allows robots to act intelligently in certain situations. These robots may be able to solve problems in a limited sphere or even learn in controlled environments.

An example of this is Kismet, which isa social interaction robot developed at M.I.T's Artificial Intelligence Lab. It recognises the human body language and also our voice and interacts with humans accordingly. Another example is Robonaut, which was developed by NASA to work alongside the astronauts in space

2.3.1   *Robot Manipulator*

A robot manipulator, also known as a robot arm, is a serial chain of rigid limbs designed to perform a task with its endeffector. Early designs concentrated on industrial manipulators, to perform tasks such as welding, painting, and palletizing. The evolution of the technical necessities of society and the technological advances achieved have helped the strong growth of new applications in recent years, such as surgery assistance, rehabilitation, automatic refuelling, etc. This section surveys those areas that have received a special, concentrated research effort, namely, industrial robots

2.3.2 *Industrial Robotics*

It was around 1960 when industrial robots were first introduced in the production process, and until the 1990s industrial robots dominated robotics research. In the beginning, the automotive industry dictated the specifications industrial robots had to meet, mainly due to the industry's market clout and clear technical necessities. These necessities determined which areas of investigation were predominant during that period. One such area was kinematic calibration, which is a necessary process due to the inaccuracy) method and the product-of-exponential (POE) formulation lead the large family of methods. A detailed discussion of the fundamentals of kinematic modeling can be found in the literature [1]. The gap between the theoretical model and the real model is found in the second stage by direct measurement through sensors. Thus, the true position of the robot's end effector is determined, and by means of optimization techniques, the parameters that vary from their nominal values are identified in the third stage. Last, implementation in the robot is the process of incorporating the improved kinematic model. This process will depend on the complexity of the machine, and iterative methods will have to be employed in the most complex cases. Research in robot calibration remains an open issue, and new methods that reduce the computational complexity of the calibration process are still being proposed . Another important research topic is motion planning,

wherein subgoals are calculated to control the completion of the robot's task. In the literature there are two types of algorithms, implicit methods and explicit methods. Implicit methods specify the desired dynamic behaviour of the robot. One implicit scheme that is attractive from the computational point of view is the potential field algorithm. One disadvantage of this approach is that local minima of the potential field function can trap the robot far from its goal. Explicit methods provide the trajectory of the robot between the initial and final goal. Discrete

explicit methods focus on finding discrete.collision-free configurations between the start and goal configurations. These methods consist mainly of two classes of algorithms, the family of road-map methods that include the visibility graph, the Voronoi diagram, the free-way method and the Roadmap algorithm , and the cell-decomposition methods . Continuous explicit methods, on the other hand, consist in basically open-loop control laws. One important family of methods is based on optimal-control strategies, whose main disadvantages are their computational cost and dependence on the accuracy of the robot's dynamic model. Besides planning robot motion, control laws that assure the execution of the plan are required in order to accomplish the robot's task. Thus, one fundamental research topic focuses on control techniques. A robot manipulator is a nonlinear, multi-variable system and a wide spectrum of control techniques can be experimented here, ranging from the simpler proportional derivative (PD) and proportional integral derivative

(PID) control to the computed-torque method, and the more sophisticated adaptive control whose details are out of the scope of this survey. Typical industrial robots are designed to manipulate objects and interact with their environment, mainly during tasks such as polishing, milling, assembling, etc. In the control of the interaction between manipulator and environment, the contact force at the manipulator's end effector is regulated. There are diverse schemes of active force control, such as stiffness control, compliant control, impedance control, explicit force control and hybrid force/position control. The first three schemes belong to the category of indirect force control, which achieves force control via motion control, while the last two methods perform direct force control by means of explicit closure of the force-feedback loop. Readers who wish to study this subject in detail will find an interesting account . An attractive alternative for implementing force-control laws is the use of passive mechanical devices so that the trajectory of the robot is modified by interaction forces due to the robot's own accommodation. An important example of passive force control is the remote center of compliance (RCC) system patented by Watson in 1978 for peg-in-hole assembly. Passive force control is simpler than active force control laws but has disadvantages, such as lacking flexibility and being unable to avoid the appearance of high contact force

1990 began, new application areas for industrial robots arose that imposed new specifications, with flexibility as the principal characteristic. The new industries that introduced

Postal services too looked for robotic systems to automate their logistics. The main requirement was the capacity to accommodate variations in product, size, shape, rigidity (in the case of foods), etc. The ability to self-adapt to the product and the environment became the issue in the following lines of investigation in the area of industrial robotics. The main line of research now is aimed at equipping the control system with sufficient intelligence and problem-solving capability. This is obtained by resorting to artificial-intelligence techniques. Different artificial intelligence (AI) techniques are used to provide the robot with intelligence and flexibility so it can operate in dynamic environments and in the presence of uncertainty. Those techniques belong to three areas of artificial intelligence: learning, reasoning and problem solving . Among the diverse learning algorithms, inductive learning is the most widely used in robotics, in which the robot learns from preselected examples . Typical reasoning paradigms in robotics include fuzzy reasoning , mostly used in planning under uncertainty, spatial reasoning, and temporal reasoning. The techniques most commonly used in robotics for problem solving are means-end reasoning, heuristic searching, and the blackboard (BB) model. Another solution to the control of robots in dynamic or unknown environments consists of introducing the operator in the control loop, such that the robot is remotely operated. The success of a teleoperation system relies on the correct feedback of the robot interaction with the environment, which can be visual, tactile or force reflection. The greatest disadvantage that tele-operated systems involve are transmission delays when the distance between the operator and the robot is significant, like in space teleoperation or over the Internet. Some research has explored solutions to this problem, such as interposing a virtual robot in charge of environment feedback, but this procedure is only valid if the robot works in structured environments. Another solution is tele-programming, in which the operator sends high-level commands and the robot carries out the task in closed-loop control. Recently, considerable attention has been devoted to Internet-based teleoperation, in which the transmission delay is variable. For direct force feedback, wave-variable-based approaches have been used extensively, and they have been further extended to include estimation and prediction of the delay

2.3.3 Medical Robots

In recent years, the field of medicine has been also invaded by robots, not to replace qualified personnel such as doctors and nurses, but to assist them in routine work and precision tasks. Medical robotics is a promising field that really took off in the 1990s. Since then, a wide variety of medical applications have emerged: laboratory robots, telesurgery, surgical training, remote surgery, telemedicine and tele-consultation, rehabilitation, help for the deaf and the blind, and hospital robots. Medical robots assist in operations on heart-attack victims and make possible the millimetre-fine adjustment of prostheses. There are, however, many challenges in the widespread implementation of robotics in the medical field, mainly due to issues such as safety, precision, cost and reluctance to accept this technology. Medical robots may be classified in many ways: by manipulator design (e.g., kinematics, actuation); by level of autonomy (e.g., preprogrammed versus teleoperation versus constrained cooperative control); by targeted anatomy or technique (e.g.,

industrial robots in their productive process were the food and pharmacy   industries

cardiac, intravascular, percutaneous, laparoscopic, micro-surgical); by intended operating environment [e.g., in-scanner, conventional operating room (OR)], etc.

Research remains open in the field of surgical robotics, where extensive effort has been invested and results are impressive. Some of the key technical barriers include safety , where some of the basic principles at issue are redundancy, avoiding unnecessary speed or power in actuators, rigorous design analysis and multiple emergency stop and checkpoint/restart facilities. Medical human-machine interfaces are another key issue that draws upon essentially the same technologies as other application domains. Surgeons rely on vision as their dominant source of feedback; however, due to the limited resolution of current-generation video cameras, there is interest in optical overlay methods, in which graphic information is superimposed on the surgeon's field of view to improve the information provided . As surgeons frequently have their hands busy, there has been also interest in using voice as an interface. Force and haptic feedback is another powerful interface for telesurgery applications . Much of the past and present work on telesurgery involves the use of master-slave manipulator systems . These systems have the ability to feed forces back to the surgeon through the master manipulator, although slaves' limitations in sensing tool-to-tissue

forces can somewhat reduce this ability. The field of medical robotics is expanding rapidly.

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