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Robotic Automation in Manufacturing

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Abstract Automation essentially describes mechanization, machines replacing human labor or human decision-making. It can have far-reaching consequences in manufacturing. It has been an important cause of job polarization in the labor market. Robotic automation is applicable to virtually any industry imaginable. It is used in manufacturing to change the industry landscape by increasing productivity, repeatability, and precision while protecting employees from unsafe working environments. This paper provides an introduction on the uses of robotic automation in manufacturing.

Keywords Automation, Robotic automation, Robotic manufacturing, Robots in manufacturing

Introduction

To boost productivity manufacturing companies turn to advanced technology such as robotic automation. Automation refers to any technology that reduces the need for human assistance. Several economists believe employment in routine occupations has declined and automation is a wave of technological change that could lead to a structural shift in the labor market and lead to "job polarization." One of the most important application areas for using automation is manufacturing. In recent years, there has been a rapid increase in the use of robots in manufacturing [1]. Robots have changed manufacturing in a myriad of positive ways. Robotic automation introduces the idea of using machines or robots to increase production while lowering costs.

What is a Robot?

The word "robot" was coined by Czech writer Karel Čapek in his play in 1920. Isaac Asimov coined the term "robotics" in 1942 and came up with three rules to guide the behavior of robots:
(1) Robots must never harm human beings;
(2) Robots must follow instructions from humans without violating rule 1,
(3) Robots must protect themselves without violating the other rules.
Robotics has advanced and taken many forms including fixed robots, collaborative robots, mobile robots, industrial robots, medical robots, police robots, military robots, officer robots, service robots, space robots, social robots, personal robots, and rehabilitation robots [2,3]. Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing.
Although there are many types of robots designed for different environments and for different purposes/applications, they all share four basic similarities [4]: (1) All robots have some form of mechanical construction designed to achieve a particular task; (2) They have electrical components which power and control the machinery; (3) All robots must be able to sense its surroundings; a robot may have light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), etc. (4) All robots

contain some level of computer programming code. Programs are the core essence of a robot since they provide intelligence. There are three different types of robotic programs: remote control, artificial intelligence, and hybrid. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. Some advantages and disadvantages of robots are shown in Figure 1 [5].

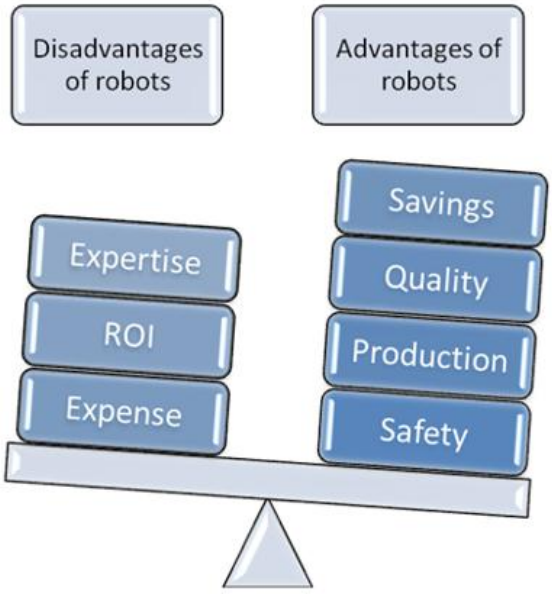

Figure 1: Some advantages and disadvantages of robots [5]

Overview on Automation

Automation refers to a wide range of technologies that reduce human intervention in processes. It has been achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic devices, and computers. There are different types of automation including artificial neural network, human machine interface, robotic process automation, supervisory control and data acquisition (SCADA), programmable logic controller (PLC), and robotics. Automation can also be classified as: (1) fixed automation, (2) programmable automation, and (3) flexible automation.

Robots exhibit varying degrees of autonomy. Autonomy means to be independent and able to govern oneself. It is different from automation, which performs a sequence of highly structured pre-programmed tasks. Industrial autonomy is where plant assets and operations have learning and adaptive capabilities that allow responses with minimal human interaction. Some companies are transitioning from industrial automation to industrial autonomy.

The main advantages of automation are [6]:

- Increased throughput or productivity
- Improved quality
- Increased predictability
- Improved robustness (consistency) of processes or product
- Increased consistency of output
- Reduced direct human labor costs and expenses
- Reduced cycle time
- Increased accuracy
- Relieving humans of monotonously repetitive work
- Required work in development, deployment, maintenance, and operation of automated processes — often structured as "jobs"
- Increased human freedom to do other things

The main disadvantages of automation are [6]:

- High initial cost
- Faster production without human intervention can mean faster unchecked production of defects
- Scaled-up capacities can mean scaled-up problems when systems fail
- Human adaptiveness is often poorly understood by automation initiators
- People anticipating employment income may be seriously disrupted by others deploying automation
- Current technology is unable to automate all the desired tasks
- Many operations using automation have large amounts of invested capital and produce high volumes of product, making malfunctions extremely costly and potentially hazardous
- As a process becomes increasingly automated, there is less and less labor to be saved or quality improvement to be gained
- As more and more processes become automated, there are fewer remaining non-automated processes

To jump directly to autonomous operations is hard to achieve [7].

Level 0-1 MANUAL/SEMI-AUTOMATED: A facility is minimally instrumented and automated improve productivity. Many operations are performed manually with paper-based instructions and record keeping.

*Level 2 AUTOMATED***:** The automation system conducts majority of production processes but requires human oversight and intervention.

*Level 3 SEMI-AUTONOMOUS***:** It is characterized by a mixture of autonomous components and automated assets with human orchestration. Companies at this level deploy a range of selective autonomous components or applications orchestrated by humans.

*Level 4 AUTONOMOUS ORCHESTRATION***:** Most assets operate autonomously and are synchronized to optimize production, safety, and maintenance. There is still a need for humans to perform many tasks.

Level 5 AUTONOMOUS OPERATIONS: A highly idealized state where facilities operate autonomously and require no human interaction.

Although perfect automation has never been realized, it has caused alterations in the patterns of employment.

Robotics in Manufacturing

Here are five types of robotic technology that have changed and will keep changing the manufacturing industry [8]:

1. Collaborative Robots
2. Autonomous Mobile Robots
3. Industrial Robots
4. Robots with Machine Vision
5. Robotic Blacksmithing

Robots are used in manufacturing for the following reasons [9]:

1. To create efficiencies all the way from raw material handling to finished product packing.
2. They can be programmed to operate 24/7 in lights-out situations for continuous production.
3. Robotic equipment is highly flexible and can be customized to perform even complex functions.
4. Manufacturers increasingly need to use robotic automation to boost productivity and stay competitive.
5. Robotic automation can be highly cost-effective for nearly every size of company.
6. Any repetitive task is a candidate for robotic manufacturing. Robots protect workers from repetitive, mundane, and dangerous tasks,
7. Robots handle tiny parts too small for human eyes and never make mistakes.
8. Robots free up manpower to let companies maximize workers' skills in other areas of the business. They create more desirable jobs, such as engineering, programming, management, and maintenance.

9. Robotic automation allows domestic companies to be price-competitive with offshore companies.
10. Robots achieve ROI quickly, often within two years, offsetting their upfront cost.

Robots used in manufacturing to perform different functions. The most common areas were robots performing their jobs in the manufacturing process include [10]:

1. *Material Handling*: Robots are being used to handle materials that require dangerous product that could risk contamination if in contact with humans.
2. *Welding:* The process of joining metal pieces is a dangerous and requires exact precision. Robots are becoming a popular choice for welding jobs. Welding robots are shown in Figure 2 [11].

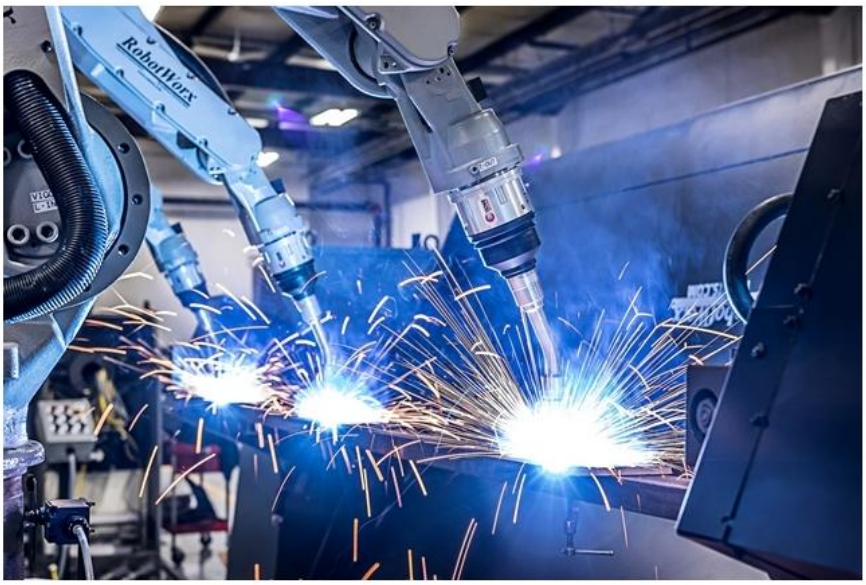

Figure 2: Welding robots [11]

3. *Assembly:* Having to assemble product parts is a long, repetitive job. By replacing such a system with a robot significantly reduce error.
4. *Dispensing:* For processes which require glue, paint, or sprays, dispensing robots are placed at a strategic point near the path of the product.
5. *Processing:* There are certain products that have to undergo a specific type of processing, such as carving, polishing, or sawing, before being released. This task is done by robots with varying degrees of autonomy.

Manufacturing Applications

Robotic automation can be applied into many different areas in manufacturing. The most common ways robotic automation is used in manufacturing include the following:

- *Automotive Industry:* This is the largest user of robots in advanced nations around the world. In particular, it is the largest customer of industrial robots. Robots are more efficient, accurate, flexible, and dependable on production lines. Robotic automation has allowed the automotive industry to remain one of the most automated supply chains globally. Different ways that robots are helping automotive manufacturers improve their automation processes include robotic vision, spot and arc welding, assembly, painting, sealing and coating, machine tending and part transfer, materials removal, and internal logistics [12]. A typical automotive manufacturing is shown in Figure 3 [13].

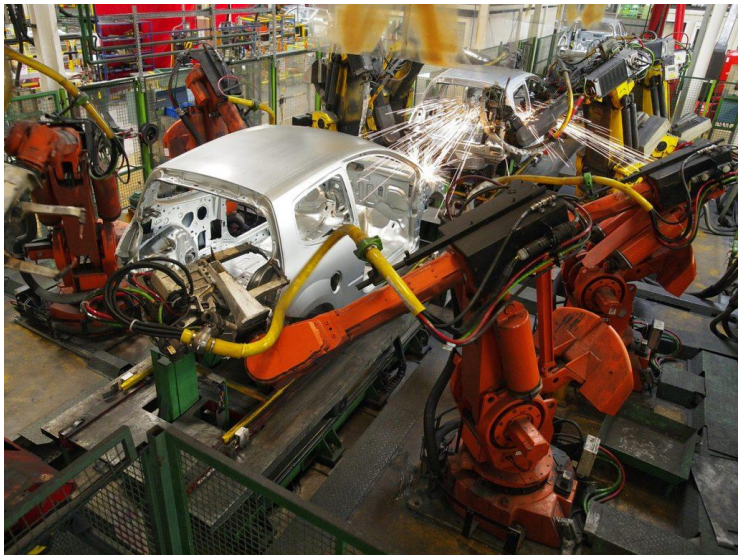

Figure 3: A typical automotive manufacturing [13]

- *Electronics Manufacturing:* Electronics manufacturing is increasingly becoming complex as the size of components and circuits continue to shrink. Robotic automation has great potential in the manufacturing of today's sophisticated electronic devices and products. It applies to almost all the stages in the electronics production cycle. It delivers a wide range of cost, quality, flexibility, and safety benefits. Typical functions include material and component handling, assembly lines, etching, inspections, soldering, and visual and physical testing, component fabrication, pick and place, assembling miniature components on PCBs, applying adhesives, inspections, and packaging. The robots can reduce the labor costs significantly by cutting on the number of employees while increasing the production times and reducing errors and wastage. Robots with arm-mounted cameras can visually inspect electronics assemblies. Figure 4 shows how a robot is used in electronic manufacturing [14].

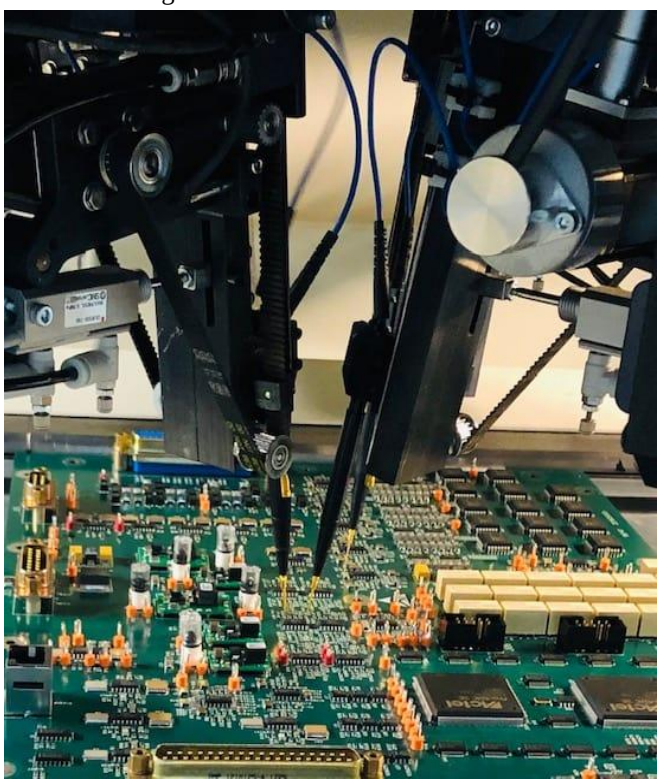

Figure 4: Robot is used in electronic manufacturing [14]

- *Lights-out Manufacturing:* This is a production system with no human workers; machines handle the production process from beginning to end to eliminate labor costs. The "lights out" manufacturing concept is so called because robots can work without lights, HVAC, coffee breaks, days off, and other conditions that human workers require. Lights-out manufacturing allows robots to work without any interference. It became popular in 1982 when General Motors replaced risk-averse bureaucracy with automation and robots. The expansion of lights out manufacturing requires reliability of equipment, preventive maintenance, and commitment from the staff. Companies that practice this manufacturing style can experience better energy efficiency [5].
- *Automated Production Lines:* This consists of a series of workstations connected by a transfer system to move parts between the stations. This is an example of fixed automation, since these lines are typically set up for long production runs. The various operations and other activities taking place on an automated transfer line must all be sequenced and coordinated properly for the line to operate efficiently. Automated production lines are used in many industries, especially automotive industry [15].
- *Robotic Processing Automation:* The manufacturing sector is leading the way as it increasingly adopts robotic process automation (RPA). RPA allows manufacturers to automate certain types of work processes to reduce the time spent on costly manual tasks. It is a critical innovation within Industry 4.0. It can automate a host of repetitive, rules-based processes, minimizing the amount of time spent on manual tasks, improving productivity, driving innovation, and lowering costs. Unfortunately, switching RPA platforms has proven to be both expensive and difficult to execute to date due to numerous other challenges. As RPA technology improves, manufacturers' RPA portfolios are likely to see a formidable rise in growth. Companies focus on getting their RPA functioning with increased stability and fewer errors [16]. Figure 5 illustrates RPA in the manufacturing industry [17].

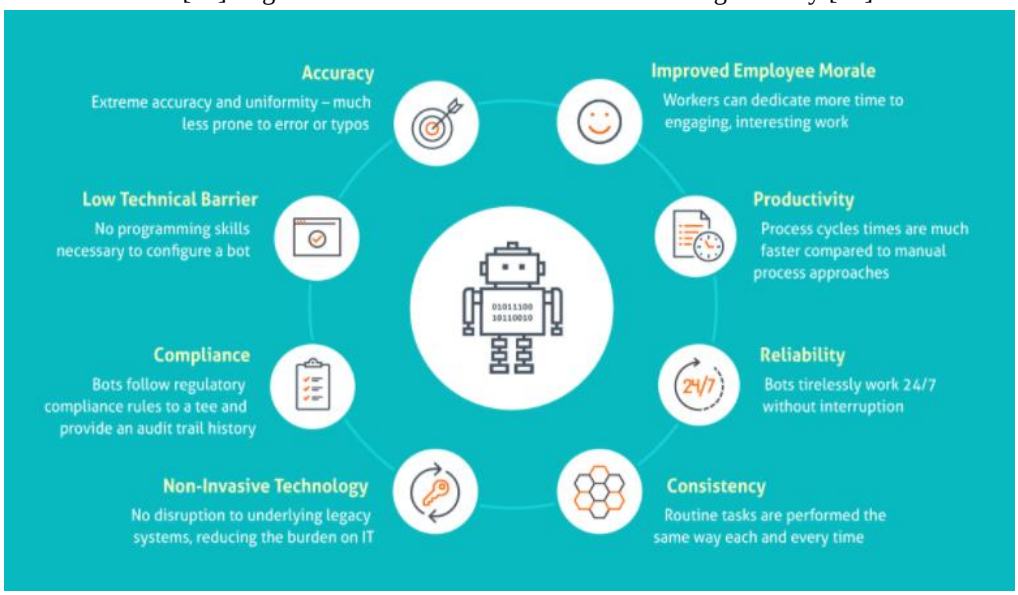

Figure 5: RPA in the manufacturing industry [17]

Some of the benefits of RPA in the manufacturing industry are illustrated in Figure 6 [18] and explained as follows: [19]:

- Error-free, consistent results
- Employees can be utilized for higher-value work
- Increased job satisfaction (not spending time doing repetitive, low-value work)
- Faster, more predictable delivery timing
- Documented trail of work performed
- Identification of anomalies or other red flags
- Up to 40% reduction in operational cost

- Increased control and visibility into end-to-end processes
- Freed up resources who can focus on more productive tasks
- Significantly lower downtime and increased quality

Other manufacturing sectors using robotic automation include food manufacturing, manufacturing forging industry, reshoring manufacturing, and robot welding,

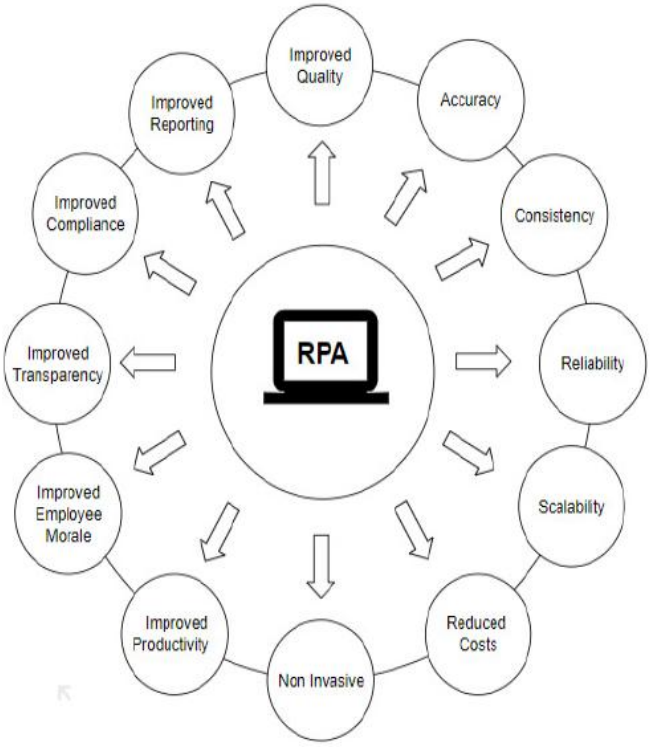

Figure 6: Benefits of RPA [18]

Benefits

Robots are evolving in ways many business professionals and production managers across the globe could only dreamed of. The key objective of robotic automation is to improve worker safety, reduce costs, improve quality, and increase flexibility. Robotic autonomous operation is a means to achieve smart manufacturing goals. The advantages of robotics include heavy-duty jobs with precision and repeatability. A robot increases speed for manufacturing processes by operating 24/7, increasing production minimizing downtime. Other benefits of robotic automation include [16]:

1. *Better Quality and Consistency*: Robots can provide better production quality and more precise and reliable processes. They can increase productivity, efficiency, and safety during process operation.
2. *Maximum Productivity:* Higher output and increased productivity have been the two of the fundamental economic advantages commonly attributed to automation. The productivity of a process is traditionally defined as the ratio of output units to the units of labor input.
3. *Greater Safety:* Using robots for repetitive tasks means fewer risks of injury for workers
4. *Reduced Direct Labor Costs:* Replacing some workers with robots frees up workers so their skills and expertise can be used somewhere else. Reduction in labor increases profit, which is always an imperative business goal.
5. *Addressing Challenges:* Robots are helping manufacturers address many of the key challenges they face, including tight labor pools, global market competitiveness, and safety.
6. *Minimize Cost:* Robotic automation is becoming increasingly flexible and intelligent minimizing cost per unit.

Challenges

Like all things, robots come with pros and cons. Some challenges facing robotic automation include [20]:

1. *High initial investment:* Robots typically require a large upfront investment.
2. *Expertise can be scarce:* Deploying industrial robot takes training and expertise from an automation company. Industrial robots need sophisticated operation, maintenance and programming. The number of people with these skills is currently limited.
3. *Ongoing costs:* While industrial robots may reduce some manufacturing labor costs, they do come with their own ongoing expenses, such as maintenance.
4. *Competition:* Many manufacturers have been compelled to send jobs offshore because they could not compete with low-cost foreign labor.
5. *Labor*: Robotic automation involves a replacement of human labor by an automated system. Workers have indeed lost jobs through automation.
6. *Stress:* A worker whose job has been placed by robots goes through a period of emotional stress. The worker may need to relocate.
7. *Limitations of Robots:* Although industrial robots remain an attractive alternative over human labor, there are still tasks robots cannot perform. Robots depend upon their surrounding systems such as vision systems, grippers, conveyors, and PLCs to complete tasks.

Despite these challenges, there are certain skills to which humans will be better suited than machines for some time to come. Humans have the advantages of creativity, decision-making, flexibility, and adaptability

Global Adoption of Robotic Automation

The use of robots has expanded globally. Germany and Italy are ahead of the US in terms of adoption of robot technology in production. The International Federation of Robotics (IFR) has data for 13 industries within manufacturing and for six broad sectors outside of manufacturing. According to IFR, there were about 2,439,543 operational industrial robots by the end of 2017. We consider how robotic automation is deployed in many countries.

- *United States:* As an area of critical importance to US and its economy, the manufacturing sector represents the largest of the US' private industry sectors. The US auto industry employed 136 robots per thousand workers, while all other manufacturing industries in the U.S employed only 8.6 robots per thousand workers. Interest in robotics increased in the late 1970s and many US companies entered the station wagon including General Electric and General Motors. Unemployment is becoming a serious social problem in the US due to the exponential growth rate of automation and technological advances.
- *China:* This is the largest industrial robot market, with 154,032 units sold in 2018. In China, which is a manufacturing hub due to cheap labor, most factories have replaced half of their workforce with robots.
- *Japan:* FANUC, a leading robot manufacturer in Oshino, Japan, has a 22-factory complex where they use the lights-out manufacturing concept to build their products. Industrial robots are supervised by a staff of only four workers per shift. In Japan, trials have demonstrated that robots can reduce the time required to harvest strawberries by up to 40 percent.
- *Canada:* The Canadian advanced manufacturing sector includes the fields of robotics, 3D printing, and ICT technologies. Canada facilitates the seamless integration of Industry 4.0 solutions into manufacturing operations.

Conclusion

Robots are all around us and their uses are increasing every day. They are taking over the world. They are rapidly changing the face of manufacturing. They are designed to perform a wide variety of programmed tasks. They may help manufacturers increase precision, repeatability, and productivity. Today, manufacturing robots are more affordable than ever before.

In the future, as demand for goods continues to grow, these robots may become more common on manufacturing floors. Future generations of robots are likely to offer higher levels of precision. Without doubt,

robots are the future of manufacturing. More information about robotic automation can be found in the books in [21-24] and the following journals devoted to robot-related issues:

- *Advanced Robotics*
- *Journal of Robotic Systems*
- *Journal of Robotics*
- *Journal of Robotic Surgery*
- *Journal of Intelligent & Robotic Systems*
- *Intelligent Service Robotics*
- *IEEE Journal on Robotics and Automation*
- *IEEE Robotics & Automation Magazine*
- *IEEE Transactions on Robotics*
- *International Journal of Medical Robotics and Computer Assisted Surgery*
- *International Journal of Robotics Research*
- *International Journal of Social Robotics*
- *International Journal of Humanoid Robotics*
- *Robotics and Autonomous Systems*

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