The Impact of Robots On Industry

Post Doctorate of Business Administration
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Abstract

Robots are growing and impacting the way society, economy and the world are organized. Areas with the lowest income, usually rural regions, are more vulnerable to the progress of automation. The permanent loss of jobs will be softened by new jobs that will be created and demand new skills from people. Automaton is likely to increase economic growth and boost productivity but it will also increase inequality among the globe and drastically change it.

1 – introduction

The presence of automation is factories began with the third industrial revolution, with increasingly advanced and intelligent machines. If a few years ago this concept was part of imagination, now they are essential to companies' industrial process.

Today, with a progressively competitive market and a gradually demanding consumer, companies are virtually facing the challenge to adopt their productive processes, using more advanced technologies, contributing to greater sustainability and optimization. With this a new industrial revolution arises, the so-called 4.0 industry, a term firstly mentioned in Germany, by the German Government in 2011, driven by the arrived of innovative technologies that contributed to industries productive processes evolution, resulting in profound changes in both companies' productive systems and businesses.

Industrial automation in companies will transform people's lives, bringing social and economic changes and an impact on jobs, in the near future.

The robotics industry is growing and it's growing fast. In 2016, the automotive industry accounted for a quite significant 43% of the total operational stock of industrial robots in global manufacturing. If you aren't getting the full picture, try this way imagine machines, probably with a whitish-grey look. Automatically controlled and reprogrammable, if they are young enough (recent ones) they are probably powered with Al or even with machine learning – and likely responsive to their surroundings.

Their hobbies go from processing materials "such as mechanical grinding" (dis) assembling, painting, precision welding, inspecting or packaging. And as technology develops, they get more in shape as their energy storage improves. They don't seem to complain and they are getting keen on interacting and collaborating with humans and optimizing productivity, especially and mostly "at least for now" in the manufacturing and logistics areas.

Just a quick throwback to the numbers since 2010, the industrial global stock of robots grew in more than half, or, indifferent words, during the last 4 years, the same number of robots were installed than in the previous 8 years, and where are they coming from and going to you wisely ask. And perhaps not surprisingly, around 1 in every 3 robots worldwide are now installed in China, in fact, the Chinese account for one-fifth of the world's total stock of robots and accounts for 35% of their global sales too. Korea, Taiwan, or India are some other big manufacturers.

Furthermore, as technology develops, processes get more sophisticated, robots become smaller, more sensitive to their surroundings and more cooperative with humans. Moreover, machine learning and the ability to learn from a huge and continuous amount of data, coming from a connected network of different robots, at an incredible speed is making robots more capable more powerful more desirable.

Regarding demand, China is expected to have nearly 8 million industrial robots in use 2030. The Chinese are already and will continue global manufacturing leaders in items such as batteries, semiconductors, and other consumer electronic devices. They are positively responding to the rising demand for manufactured goods and positioning themselves right in the heart of these changes for the long term.

2 – What Is Robotics?

Robotics is intersection of science, engineering and technology that produces machines, called robots, that substitute for or replicate human actions. Pop culture has always been fascinated with robots. R2-D2, Optimus prime. WALL-E., these over-exaggerated, humanoid concepts of robots usually seem like a caricature of the real thing; or are they more forward thinking than we realize? Robots are gaining intellectual and mechanical capabilities that don't put the possibility of a R2-D2- like machine out of reach in the future.

What is a robot?

A robot is the product of the robotics field, where programmable machines are built that can assist humans or mimic human actions. Robots were originally built to handle monotonous tasks (like building cars on an assembly line), but have since expanded well beyond their initial uses to perform tasks like fighting fires, cleaning homes and assisting with incredibly intricate surgeries. Each robot has a differing level of autonomy, ranging from human-controlled bots that carry out tasks that a human has full control over to fully-autonomous bots that perform tasks without any external influences.

3 – Types of Robots

Mechanical bots come in all shapes and sizes to efficiency carry out the task for which they are designed. All robots vary in design, functionality and degree of autonomy, from the 0.2 millimeter-long "RoboBee" to the 200-meter-long robotic shipping vessel "Vindskip," robots are emerging to carry out tasks that humans simply cannot. Generally, there are five types of robots;

First, pre-programmed robots

Pre-programmed robots operate in a controlled environment where they do simple, monotonous tasks, an example, of a pre-programmed robot would be a mechanical arm on an automotive assembly line. The arm serves one function to weld a door on, to insert a certain part into the engine, and its job is to perform that task longer, faster and more efficiently than a human.

Second, Humanoid robots

Humanoid robots are robots that look like and or mimic human behavior. These robots usually perform human-like activities (like running, jumping and carrying objects), and are sometimes designed to look like us, even having human faces and expressions. Two of the most prominent examples of humanoid robots are Hanson Robots Sophia and Boston Dynamics'' Atlas.

Third, Autonomous Robots

Autonomous robots operate independently of human operators. These robots are usually designed to carry out tasks in open environments that don't require human supervision, they are quite unique because they use sensors to perceive the world around them, and then employ decision-making structures (usually a computer) to take the optimal next based on their data and mission. An example of an autonomous robot would be the Roomba vacuum cleaner, which uses sensors to roam freely throughout a home.

Examples of autonomous robots

A – Cleaning Bots like Roomba; B – Lawn Trimming Bots; C – Hospitality Bots; D – Autonomous Drones; E – Medical Assistant Bots.

Four, Tele operated Robots

Tele operated robots are semi-autonomous bots that use a wireless network to enable human control from a safe distance. These robots usually work in extreme geographical conditions, weather, circumstances, example of tele operated robots are the human-controlled submarines used to fix underwater pipe leaks during the BP oil spill or drones used to detect landmines on a battlefield.

Five, Augmenting Robots

Augmenting robots either enhance current human capabilities or replace the capabilities a human may have lost. The field of robots for human augmenting is a field where science fiction could become reality very soon, with bots that have the ability to redefine the definition of humanity by making humans faster and stronger. Some examples of current augmenting robots are; robotic prosthetic limbs or exoskeletons used to lift hefty weights.

4 – How do robots function

Independent robots

Independent robots are capable of functioning completely autonomously and independent of human operator control. These typically require more intense programming but allow robots to take the place of humans when undertaking dangerous, mundane or otherwise impossible tasks, from bomb diffusion and deep-sea travel to factory automation. Independent robots have proven to be the most disruptive to society, eliminating low-wage-jobs but presenting new possibilities for growth.

Dependent robots

Dependent robots are non-autonomous robots that interact with human to enhance and supplement their already existing actions. This is a relatively new form of technology and is being constantly expanded into new applications, but one form of dependent robots that has been realized is advanced prosthetics that are controlled by the human mind.

A famous example of a dependent robot was created by John Hopkins APL, in 2018 for a patient named Johnny Matheny, a man whose arm was amputated above the elbow, Matheny was fitted with a Modular prosthetic limb (MPL) so researcher could study its use over a sustained period. The MPL is controlled via electromyography, or signals sent from his amputated limb that controls the prosthesis. Over time, Matheny because more efficient in controlling the MPL, and the signals sent from his amputated limb because smaller and less variable, leading to more accuracy in its movements and allowing Matheny to perform tasks as delicate as playing the piano.

ISSN 2229-5518

What are the main components of a robot?

****- control system***
****- sensors***
****- power supply***
****- end effectors***

Main components of a robot
Robots are built to present solutions to a variety of needs and fulfill several different purposes, and therefore, require a variety of specialized components to complete these tasks. However, there are several components that are central every robot's construction, like a power source or a central processing unit. Generally speaking, robotics components fall into these five categories;

Control system
Computation includes all of the components that make up a robot's central processing unit, often referred to as its control system. Control system are programmed to tell a robot how to utilize its specific components, similar in some ways to how the human brain sends signals throughout the body, in order to complete a specific task. These robotic tasks could comprise anything from minimally invasive surgery to assembly line packing.

Sensors
Sensors provide a robot with stimuli in the form of electrical signals that are processed by the controller and allow the robot to interact with the outside world. Common sensors found within robots include video cameras that function as eyes, photoresists that react to light and microphones that operate like ears. These sensors allow the robot to capture its surroundings and process the most logical conclusion based on the current moment and allows the controller to relay commands to the additional components.

Actuators
As previously stated a device can only be considered to be a robot if it has a movable frame or body, actuators are the components that are responsible for this movement. These components are made up of motors that receive signals from the control system and move in tandem to carry out the movement necessary to complete the assigned task. Actuators can be made of a variety of materials, such as metal or elastic, and are commonly operated by use of compressed air (pneumatic actuators) or oil (hydraulic actuators), but come in a variety of formats to best fulfill their specialized roles.

Power supply
Like the human body requires food in order to function, robots require power, stationary robots, such as those found in a factory, may run on AC power through a wall outlet but more commonly, robots operate via an internal battery. Most robots utilize lead-acid batteries for their safe qualities and long shelf life while others may utilize the more compact but also more expensive silver-cadmium variety, safety, weight, replace ability and lifecycle are all important factors to consider when designing a robot's power supply.
Some potential power sources for future robotic development also include pneumatic power from compressed gasses, solar power, hydraulic power,

flywheel energy storage organic garbage through anaerobic digestion and nuclear power.

End effectors

End effectors are the physical typically external components that allow robots to finish carrying out their tasks, robots in factories often have interchangeable tools like paint sprayers and drills, surgical robots may be equipped with scalpels and other kinds of robots can be built with gripping claws or even hands for tasks like deliveries, packing, bomb diffusion and much more.

5 – Uses of Robots

Robots have a wide variety of use cases that make them the ideal technology for future, soon, we will see robots almost everywhere. We will see them in our hospitals, in our hotels and even on our roads.

Applications of Robotics

****- Helping fight forest fires***
****- working alongside humans in manufacturing plants (known as co-bots)***
****- robots that offer companionship to elderly individuals***
****- surgical assistants***
****- last-mile package and food order delivery***
****- autonomous household robots that carry out tasks like vacuuming and mowing the grass***
****- assisting with finding items and carrying them throughout warehouses***
****- used during search and rescue missions after natural disasters***
****- landmine detectors in war zones***

Manufacturing

The manufacturing industry is probably the oldest and most well-known user of robots. These robots and co-bots (bots that work alongside humans) work to efficiently test and assemble products, like cars and industrial equipment. Its estimated that there are more than three million industrial robots in use right now.

Logistics

Shipping, handling and quality control robots are becoming a must-have for most retailers and logistics companies. Because we now expect our packages to arrive at blazing speeds, logistics companies employ robots in warehouses, and even on the road, to help maximize time efficiency. Right now, there are robots taking your items off the shelves, transporting them across the warehouse floor and packaging them. Additionally, a rise in last-mile robots (robots that will autonomously deliver your package to your door) ensure that you will have a face-to-face encounter with a logistics bot in the near future.

Home

It's not science fiction anymore. Robots can be seen all over our homes, helping with chores. Reminding us of our schedules and even entertaining our kids. The most well-known example of home robots is the autonomous vacuum cleaner Roomba. Additionally, robots have now evolved to do everything from autonomously mowing grass to cleaning pools.

Travel

Is there anything more science fiction-like than autonomous vehicles? These self-driving cars are no longer just imagination. A combination of data science and robotics, self-driving vehicles are taking the world by storm. Automakers, like Tesla, ford, Way Mo, Volkswagen and BMW are all working on the next wave of travel that will let us sit back, relax and enjoy the ride. Rideshare companies Uber and Lyft are also developing autonomous rideshare vehicles that don't require humans to operate the vehicle.

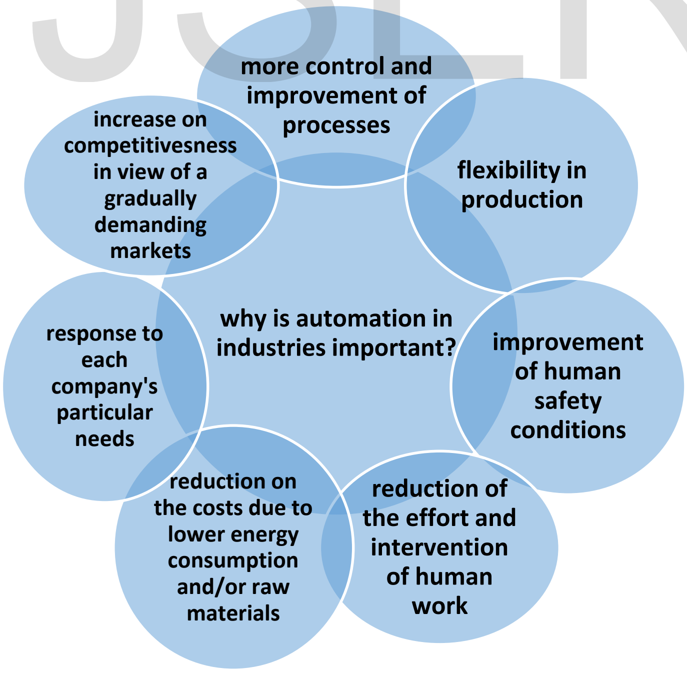
Healthcare

Robots have made enormous strides in the healthcare industry. These mechanical marvels have use in just about every aspect of healthcare, from robots-assisted surgeries to bots that help humans recover from injury in physical therapy. Examples of robots at work in healthcare are Toyota's healthcare assistants, which help people regain the ability to walk, and "TUG," a robot designed to autonomously stroll throughout a hospital and deliver everything from medicines to clean liners.

Recently, robots have been employed by pharmaceutical companies to help speed up the fight against COVID-19. These bots are now being used to fill and seal COVID-19 testing swabs, and are also being used by some manufacturers to produce PPE and respirators.

2 – why is automation in industries important?

Automation is essential for the evolution of industrial processes, with countless advantages to the productive system, such as:



The so-called smart plants will use a set of technologies such as Artificial Intelligence (AI), Robotics, Big Data (IOT) and Data Protection, that will allow automatic operation and enabling to process small and /or repetitive tasks, preventing, and avoiding technical failures that might jeopardize the productive process.

2 – 1. More control and improvement of processes

Process improvement involves the business practice of identifying, analyzing and improving existing business processes to optimize performance, meet best practice standards or simply improve quality and the user experience for customers and end-users.

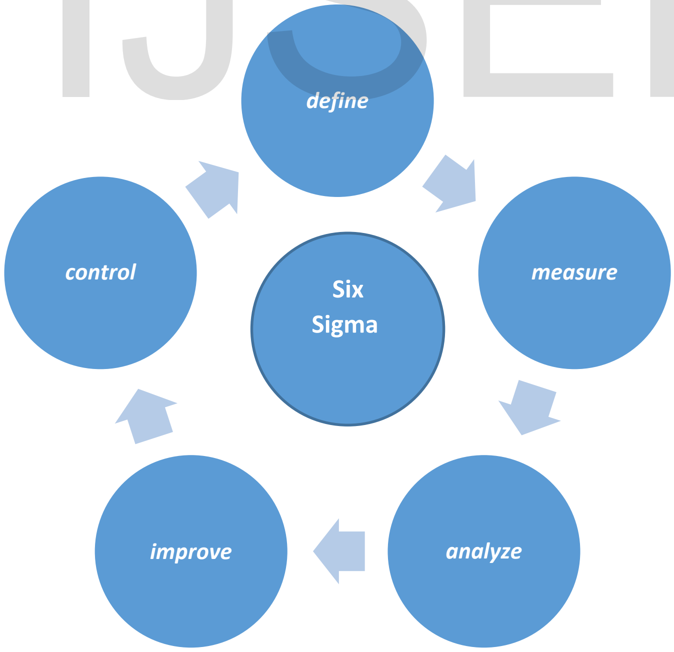
Process improvement describes a business practice of identifying and analyzing existing businesses processes and implementing changes to meet best practice standards, optimize performance, or simply improve user experience.

Process improvement can have several different names such as business process management (BPM), business process improvement (BPI). They all pursue the same goal: to minimize errors, reduce waste, improve productivity and streamline efficiency.

Process improvement techniques;

There are several different business process improvement methodologies your team can use to help reduce inefficiencies. In most cases, the methodology you choose depends on why you want to improve your processes and what you are looking to improve.

****- Six Sigma***
Six Sigma is a popular methodology that pulls employees up through ranks classified similarly to Karate belts. You start out as a green belt and, over time, advance all the way up to a black belt. Six Sigma included two different ways to break down process improvement into steps: DMAIC (define, measure, analyze, improve, control) and DMADV (define, measure, analyze, design, verify).



Define the opportunity for improvement;

Measure the performance of your existing processes;

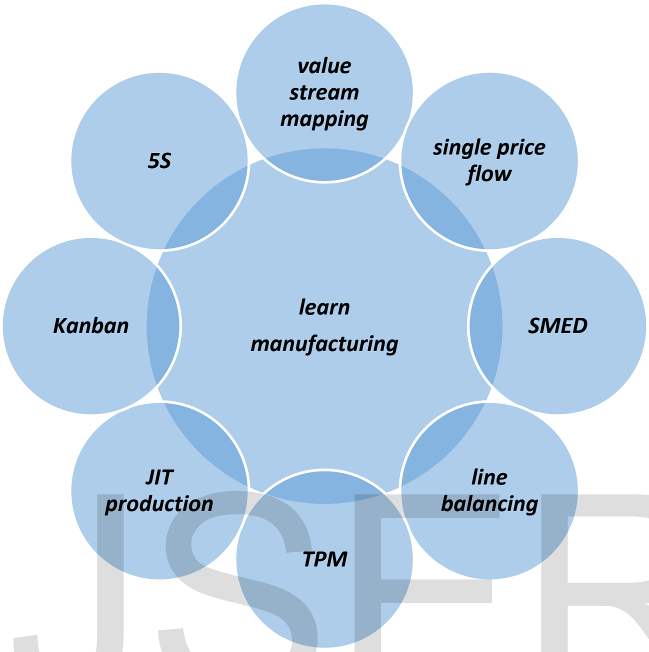
Analyze the process to find defects and root causes;

Improve processes by addressing root causes;

Control any improved process and assess future process performance to correct deviations.

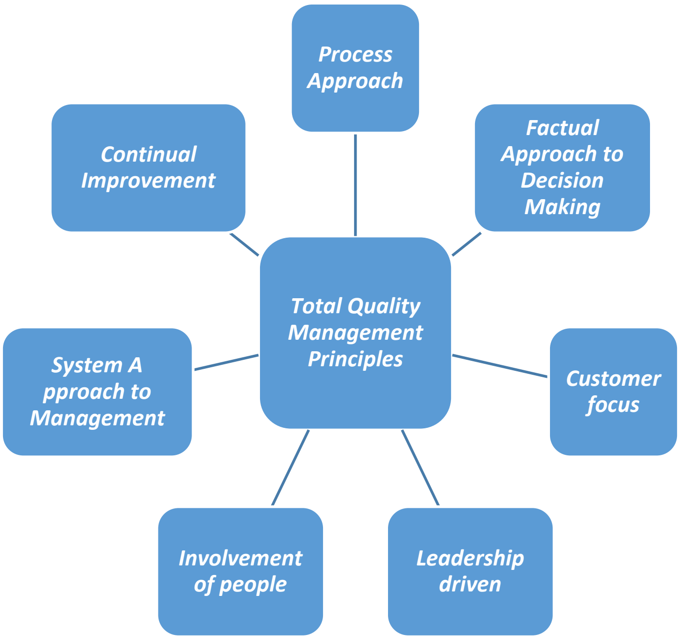
****- Learn Manufacturing***

The learn methodology's goal is to reduce costs by eliminating waste. Despite its name, learn manufacturing's ideas can be applied to any organization or process, not just manufacturing. Someone using this technique would evaluate the value stream of a process. Anything that doesn't add value is considered to be waste and should be eliminated.



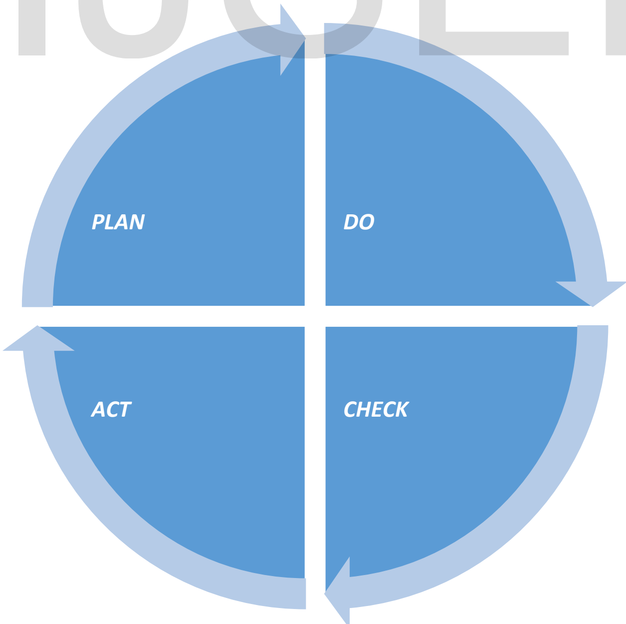
****- total quality management (TQM).***

TQM is focused on creating long-term success through customer satisfaction. It's a technique that fosters a culture where employees are driven toward a shared goal and aren't afraid to make mistakes. TQM creates continuous process improvement within the organization and gets the entire company on board with it.



- Plan – Do – Check – Act (PDCA).

PDCA methodology helps organizations identify processes that need to be improved in a more efficient way. First, you identify the problem (plan), then generate and implement a solution (do), evaluate data to make sure it is effective (check), and, finally, implement the plan if it's successful (act). It's a type of process management tool to let you do your operational tasks more effectively.



- Cause and Effect Analysis (CEA).

Cause and effect analysis involves using diagrams to fix issues by identifying the problem, finding the roadblocks, and pinpointing the reason why the process isn't working.

- Value Stream Mapping (VSM).

VSM aids in providing a visual representation of your customers' perception of a business process, which help to identify the value of a service, product, or process of the organization. This method is focused on eliminating redundancy. Waste, and being as lean as possible.

2 – 2. flexibility in production

Flexibility is widely recognized as one of the most important dimensions of a successful manufacturing strategy (1) . Various quantitative models have been developed over the years to study its different facets. In applications, the relevant notion of flexibility, its measure and its properties, very much depend on the specific details of the particular production and operations environment. This justifies the need for a large number of models, each fine-tuned to the specificities of a particular context. A principal goal is to identify generic properties that are shared by different models of flexibility(2)

If the various existing models address the problem of flexibility in many different contexts, they also leave unexplored situations; for example, what is the relevant concept of flexibility in the context of queuing network models of manufacturing?

Another goal is to provide a road map for the investigation of such a question. Although the context considered is more general, the analysis is strongly related to a model of output-flexibility under a stochastic demand by Marshak and Nelson (1962)(3) And to a model of decision-making under uncertainly by Jones and Ostroy (1984)(4) The formal model is also closely connected to the theory of lattice programming introduced by Topkis (1978)(5) And recently applied by Milgram and Roberts (1990)(6) to the economic analysis of modern manufacturing technologies.

2 – 2.1 four advantages of flexibility in production

Flexible manufacturing is a system that allow a certain level of adaptability, making it easy to react to changes, whether predictable or unpredictable. This method is particularly valued in the automotive industry because it allows rapid product switches with minimum downtime. This enables the industry to respond to customer orders quickly by introducing new products effortlessly and by providing a broad product range.

Flexible production covers two main areas. On one side it focuses on use flexibility in managing resources like time and effort by developing a skill-flexible core workforce. On the other side, it provides machine flexibility which increases the resilience in processes as the manufacturing system absorbs large-scale changes such as production assortment size. Capacity, and productivity. This system stands out because it doesn't follow a fixed set of steps. The process changes according to efficiency and operations.

2 -2.2 History of flexible production

In order to understand how flexible manufacturing impacts the product life cycle, direct workforce and market circumstances, it makes sense to take a step back in the past. Flexible production hasn't always been a standard in manufacturing. In fact, for a long time, you could argue that production has been quite "inflexible", especially during the era of Henry ford, mainly distinguished by the same standard mass-production items where there wasn't an urgent need for efficiency. Wherever, as soon as the Second World War disrupted the whole world, it started affecting also the manufacturing industry. With a shortage of goods and workforce, companies had to adapt by introducing new materials

and technologies. The world conflict prompt also to an opening of the markets while leading to more competition.

2 – 3. Improvement of human safety conditions

The impact of automation on health and safety on a macro level isn't well studied as its impact on jobs or productivity. Levert and Hery (2018)(7) presented two sides of the coin; automation might be a contributing factor to work load intensification but it can also reduce physical demands and repetitive tasks. While the report suggested that work load intensification could be the reason for an increase in work-related incidents, this theoretical hypothesis isn't well matched by real world statistics. The occupational incidence rate in the U.S. private sector and U.S. poultry industry has been falling in the past 15 years, which coincided with the intensification of automation in general.

Researchers hope that robots' automation, including new technologies that might help sort difficult materials before they ever reach human hands, will help improve the efficiency of the process." Robotic research has made groundbreaking advancements in manufacturing industry, healthcare technology and search and rescue, among many others, but how robots can help us achieve an environmentally sustainable future has been overlooked for the most part, " said Calli. "one goal of my lab is to expand the field of environmental robotics. Incorporating robots into recycling facilities is a natural fit."

Other investigators include Brian Scassellati, from the Yale Social Robotics lab, Barbara Reck, an industrial ecologist at F&ES; Amy Wrzesniewski, Michael H. Jordan professor of Management at the Yale School of Management; Jacob Whitehil, an assistant professor of computer science at WPI; Kate Saenko, an associate professor of computer science at Boston University (BU); and Vitaly Ablavsky, a senior research scientist in computer science at BU.

The U.S. scrap recycling industry represents about $117 billion in economic activity annually and more than 530,000 jobs. Many of these workers are employed at material recycling facilities (MRFs), where waste is sorted and prepared for end users. These centers, however, rely heavily on the perception and judgment of workers who are asked to manually sort through piles of waste – including a mix of plastics, paper, metal, glass, and non-recyclables – that travel down conveyer belts. Workers are asked to identify and handle a complex variety of waste under frequently dangerous and difficult conditions, including hazards related to large and heavy items, toxic materials, and loud noises.

Working with MRF operators, the Yale-led research team will explore whether sorting processes can be improved through the integration of new technologies – including advances in object detection, manipulation, and human – robot interaction – that might automatically remove some of these hazards before they reach human sorters.

Wrzeniewski, from Yale school management, will study the relationship between human and robots in order to improve worker safety, the quality of the jobs, and worker motivation. Wrzeniewski, who studies how people make meaning of their work in difficult contexts, will examine how workers currently employed at these recycling centers understand their roles now and the potential impact of technological changes.

2 – 4. Reduction of the effort and intervention of human work

Performing manual tasks takes time, and multi-tasking isn't something we are good at. So, most work done by human is performed in a linear fashion, and this is rarely the most effective use of time and resources. By eliminating manual work through automation we

can save time, but that isn't the sole benefit driver here. In addition, to being linear work processes, human is prone to error- we aren't robots. The introduction of error further loses time in operations, either at the time of performing the work, or of greater impact, downstream. Automating work minimizes human intervention in the workflow, and in turn this removes the ability for people to generate error. Minimizing error not only improves consistency of work quality, but also results in significant time saving too.

By defining workflows that control associated tasks and work, you will be able to start measuring work itself. Once your workflows are in place, it is a simple step to start times or counts per period at the major nodes, such as time elapsed from a task entering a workflow to leaving it, and placing multiple checkpoints within a workflow to see where a bottleneck or opportunity for improvement exists.

Because workflows are themselves controlled by the automated processes within a process management tool (here we call this a BPMS or BPM software,) you are able to achieve consistency, accuracy, and timeliness of data recording.

By delivering reliable business data, almost on a real-time basis, which is already in a digital format and therefore open to data analysis and manipulation, you are able to create business advantage, which in turn opens the door to developing winning business strategies.

2 – 5. Reduction on the costs due to lower energy consumption and / or raw materials

Over the past 50 years, the need to reduce costs and cut manufacturing time in an even bigger market, with new countries competing in the space, lead to a flexible production system, making it the essential driving force, especially in the automotive industry.

In this blog post, we want to share with you what are the main advantages of flexible production and how it can allow manufactures to be the fastest on market, operating with lower total cost and greater ability to satisfy their customers.

"automation has historically brought down the costs and increased the quality of numerous manufacturing processes," said Aaron Dollar, a professor of mechanical engineering and materials science at the Yale School of Engineering and Applied Science and Yale's principal investigator for the research. "we want to see what we can do along those lines in order to help the important but troubled recycling industry".

This is frequently the most touted benefit of work automation, however, you should use it with judicious care. Saving money always sounds like a great idea, but experienced executives understand that delivering ROI is much more than simply reducing the cost element in the equation. For instance, cost reduction is frequently thought to be achieved by headcount reductions. But are you losing institutional knowledge and skill as a result?

Nevertheless, work automation does generate significant cost savings because of increased speed of operations, fewer errors, reduced resource utilization, and of course, smaller of staff needed to deliver the same output.

2 – 6. Response to each company's particular needs

Business process automation (BPA) uses technology to automate day-to-day tasks, manual functions, and organized systems and workflows for all personal. Most companies use some form of business process automation software in various areas of their enterprise. After all, automation can cut operating costs by up to 90%, according to Forrester.

With BPA, you can automate;

A – customer relationship

B – analysis

C – planning

D – sales

The three main tenets of business process automation are;

****- Allow companies to command, organize, and automatically execute strategies and tool***
****- Centralized work processes and integrate functions across the company.***
****- Minimize human involvement in menial tasks.***

The goal is to support your employees, minimize operational costs, cut down on human error, streamline work processes, and provide better customer service. Business process automation continues to gain popularity and adoption because it delivers a heap of benefits to your company.

The three elements of automated business system;
1 – Business rules and logic. 2 – structured data. 3 – unstructured data.
Business rules and logic
Business rules and logic refers to the resources that define your business parameters
****- stipulations. *- reasons. *- data. *- documents.***
Some of this can be completely automated, but they all need to be reviewed beforehand because some processes still require manual effort.

Structured data
Structured data is the information stored in the applications on your companies or other machines. Phone numbers, social security numbers, Zip codes, names. The data is well organized, easily searchable, and stored in a relational database management system (RDBMS).

Unstructured data
Unstructured data is subjective, random, and difficult to organize information. It's typically heavy on text and requires considerable focus to sift through. But this type of data drives some of the biggest business decisions you will make. Unstructured data can come from social media just as readily as it can come from a conversation over lunch-making it difficult to organize and format into a reliable structure of rows and columns.

2 – 7. Increase on competitiveness in view of a gradually demanding market

As the competition intensifies in the market for products and services and the need for recognition, companies in their effort to reduce operating costs see automation as a solution. While how much of and to what extent the process is

to be automated to avoid the deployment of manpower is still engaging the attention of corporate and researchers. While automation provides predictable, consistent performance, it lacks judgement, adaptability and logic, they are unpredictable, inconsistent and subject to emotions and motivation. To optimize performance in an organization, we do minimize human input and lose efficient, consistent, error-free system performance from automated the process.

Robots increase productivity and competitiveness used effectively, they enable companies to become or remain competitive. This is particularly important for small to medium sized (SME) businesses that are the backbone of both developed and developing country economics. It also enables large companies to increase their competitiveness through faster product development and delivery increased use of robots in also enabling companies in high cost countries to "reshore", or bring back to their domestic base parts of the supply chain that they have previously outsourced to sources of cheaper labor currently, the greatest threat to employment isn't automation but an inability to remain competitive.

Automation has led overall to an increase in labor demand and positive impact on wages. Whilst middle-income / middle – skilled jobs have reduced as a proportion of overall contribution to employment and earnings- leading fears of increase income inequality- the skills range within the middle- income bracket is large robots are driving an increase in demand for workers at the higher-skilled end of the spectrum, with a positive impact on wages. The issue is how to enable middle- income earners in the lower-income range to upskill or retrain.

Robots complement and augment labor; the future will be robots and humans working together. Robots substitute labor activities but don't replace jobs. Less than 10% of jobs are fully automatable increasingly, robots are used to complement and augment labor activities; the net impact on jobs and the quality of work is positive automation provides the opportunity for human to focus on higher-skilled, higher-quality and higher-paid tasks.

3 - Distributed Robotic Systems

The term "distributed Robotic Systems" traditionally refers to a set of geographically distributed mobile robot systems which may exploit wireless communication to share in formation and coordinate tasks. We adopt a more inclusive definition in which the robotic systems may comprise traditional mobile robot systems in the large, for example mobile robot system for outdoor surveillance, in the small, for example swarm robotic systems or distributed mobile sensing units, and fixed robotic modules including geographically distributed sensors and actuators as in wireless sensor and actuator networks. We adopt in addition a modular service-oriented viewpoint in which the sensors and actuators within a traditional robot system, and these fixed sensor and actuator systems are modules offering a range of functionality and connectivity, and possess both geographic and network location.

The approach we adopt can be likened to the multi-agent systems approach for it requires software components that can listen and respond to queries (15),*[8] *offer services to other modules and in the ideal case some will also possess mobility so that they can relocate to network nodes with free resources or where they are closer to modules with which they are directly connected. However, multi-agent systems research tends to focus on agents that are automations with proactive, reactive, and social decision making and interaction. The approach we have followed treats the modules more as the components of a system, with each modules providing services to one or more other modules, and all modules working in their own way towards the operation of a distribution robotic system. In this respect it is more appropriate to think of the modules as being wired together into a multi-level architecture even though the modules themselves are geographically distributed.

4 - Cooperating Robots Systems

The term "multi-robot system" can be used to refer to a wide range of robotics system incorporating more than one robot, including swarms of many robot system and smaller robot teams for competitions such as Robocop (17)*[9] *The term is used in this section to refer to heterogeneous teams of mini or large mobile robot systems, including the teams for example in the Middle Sized League of Robocop. Such systems typically incorporate wireless Ethernet as the basis for communication, vision based sensing, an on-board computer, possibly a laptop, and hence the ability to support a greater level of autonomy as well as robot-robot and human-robot cooperation.

***There are four general challenges that can be identified in the research literature. First, how do we ensure that the robots stay within range of each other so that a communications network is maintained encompassing all the robots (e.g. (18) (19))*[10]**

Second, in a cooperative sensing or surveillance task. How do we ensure that the area that is to be surveyed is adequately covered (e.g. (20))*[11] *? This includes elements of target allocation, in that each robot needs to be allocated or determine an area to be monitored. Third, in a cooperative mapping task, how is the information from the local maps built by each robot integrated to provide a global map (17)*[12] *? Fourth, in a robot team that is to perform some task that can be broken out into subtasks, how should the sub-task be allocated to the robots in the team (e.g. (21) (22)*[13] *?

Cooperating multi-robot systems can generally be classified as loosely coupled multi-robot systems since the robots are associated in the completion of a task but aren't physically coupled to other members of the robot team. In contrast, robot systems which are involved for example in the cooperative transport of extended payloads and are therefore, physically coupled by means of the object being transported can be classified as tightly coupled multi-robot systems. In the first case the communication between the robots is largely explicit, network-based, while in the second case the robots can take advantage of implicit communication via the connecting payload.

***Tightly coupled operation of multiple robot systems is required when two or more robots are working together to manipulate an extended object. These studies cover work in the area of dual manipulate system (e.g. (23) (24))*[14]**

and in mobile robot mounted manipulator systems (25) (26) (27) (28)*[15] *We will focus on cooperating multi-robot systems for carrying an extended payload, reporting in particular the research carried out at the NASA/CALTECH Jet Laboratories and in the Active Robotics Laboratory at the University Reading.

Research in the area of multiple robots collectively carrying a shared object has been pursued in the context of space robotics missions, specifically scenarios in which a Habitat is prepared for human arrived on Mars (26)*[16] *A particular task associated with the preparation of a human habitat on Mars involves the deployment of PVC tents to harness power from the sun. the scenario involves a container storage unit (CSU) containing a set of PVC tents and a cooperating pair of robots to;

1 – approach and pick up individual PVC units from the CSU,

2 – transport the units to the target site, and

***3 – set down the units at the destination site (29)*[17]**

This is repeated until all units are deployed.

***The research in the Active Robotics Laboratory at the university of reading, focused on the overall design of the dual robot system to support the task, including pickup, traverse and set down, and tasks its inspiration from work carried out at the UCLA/NASA jet propulsion laboratory (26)*[18] *Both sets of work assume a hybrid architecture, in JPL's work this is referred to as the CAMPOUT architecture (29)*[19] *combining deliberate top-down planning of the task and lower level behavior-based control for immediate robot-robot interaction during transport. However, neither has implemented the deliberative component, opting to focus on designing the behavior-based coordination and defining the overall task structure manually. Both have employed implicit communication based on sensing the motion of the payload in the grippers when cooperatively carrying the payload, though the JPL work has implemented also explicit communication between the robots for synchronization. Both sets of work demonstrated practical systems and the JPL work was successfully demonstrated in outdoor terrain. The work at the university of reading focused on specific behavioral aspects of the architecture, opting to manually set and unset behavior sets for each component of the task (27)*[20]**

An area of future work is to explore multi-team, multi-robot system. A flexible and robust multi-robot system must incorporate within individual robots and across the team the heterogeneity needed to support a wide-range of tasks. This is an important challenge for multi-robot system research and therefore has implications for network robotics. This will require providing support for explicit communication and coordination between the robots in a team. In addition, a number of robot teams may be formed within a multi-robot system, and even within one or more of these teams further structuring as sub-teams may be required. It should also be possible for robots to move between teams as the requirements on a set of tasks changes. Explicit communication is then required not only between individual robots but also between robot teams.

A space robotics application involving the cooperation transport of an extended payload can be used to illustrate the multi-team multi-robot concept. Assume

that a heterogeneous pool of robots is provided from which robot teams can be drawn. The selection process involves the identification of roles and then the allocation of robots to the teams that fulfil these roles. In the transportation task robot teams are required to respectively carry an extended payload, clear a path across the terrain for the transport of the payload and scout a route to the destination. These three teams can be called the "carriers", the "clearers" and the "scouters" respectively.

The scouters will need to coordinate with each other to explore and select a suitable path through the terrain between the origin and the destination. They will then need to communicate the selection to the clearers and also to the carriers. The clearers need to coordinate with each other to clear rocks and flatten the terrain along the path. Keeping ahead of the carriers. Clearing the path may involve the formation of loosely and tightly coupled sub-teams within the clearing team. Tightly coupled coordination may be required for example to push aside a large rock. The clearers need to coordinate with the scouters and the carriers to confirm that the path (ahead) of the carriers has been cleared. The carriers are responsible for picking up the object to be transported, carrying it along a path and setting it down or assembling it at a destination. This is a tightly coupled operation requiring coordination between the robots in the teams to allocate grasp points, synchronies on pickup and cooperate on traversal.

Each robot will need to ensure that it has the resources to perform its role and to evaluate satisfactory completion of its role. The robots within each team must also synchronizes to ensure that the task assigned to its team has been satisfactorily completed. Moreover, there is a dependency between the teams since the scouters must provide the route that the clearers need to clear in preparation for the carriers to move the payload. However, these threes activities can proceed in parallel provided the scouters task stays ahead of the clearers task and the clearers task in turn stays ahead of the carriers' task. Within this setting it is also possible to envisage robots moving between teams as the level of difficulty of the three tasks changes, facilitating a still more flexible and robust multi-robot system.

5 – Swarm Robots System

One area where inter-robot communication is relevant is swarm robotic system. Robots in these systems are minimalist and therefore simple communication techniques, short-range communication and economic messaging are the norm. however, within existing approaches to communication within swarm system there is no systemic means to determine the communication requirements except at the level of individual message. There isn't means for example to determine how many message may need to be communicated per second and the scope of individual communications-whether peer-to-peer, peer-to-group or group-to-group. This can be addressed if there was a mathematical model for swarm systems. However, a review of the literature revealed that such a model was missing. The lack of such a model motivated research reported elsewhere aimed specifically at the development of such a model (30) (31)[21] This model provides a framework within which to study the communication requirements of a swarm robotic system.

The mathematical model addresses a number of challenges (32)[22] including obstacle avoidance, collision avoidance and transformation of swarm patterns. The model is based on the complex plane; swarm robotic agents are placed on the roots (vertices) of a complex equation to form a polygonal pattern. The parameters that define the mathematical model are classified as microscopic and microscopic. Macroscopic parameters define group or abstract behaviors of the swarm system whereas microscopic parameters define individual agent behaviors. Many experimental test-beds for swarm robotic system, for example mission lab (33) (34)[23] are based on microscopic parameters. This means they focus on peer-to-peer communication between the robots.

Pattern transformation is a key aspect of swarm systems. Obstacle avoidance for example can be treated within swarm systems as pattern transformation. For example, a swarm of robots in a polygonal pattern needs to transform to a linear pattern to traverse through a narrow path and then transform back to the previous pattern on reaching the far side. The challenge of pattern transformation was addressed in the mathematical model with two feasible tools, the first a non-mathematical tool (35)[24] and the second a mathematical tool (36)[25] The first was based entirely on macroscopic parameters while the second, which employed Mobius transformations, incorporated both macroscopic and microscopic parameters.

In both methods, attention has to be paid to ensuring that the robots don't collide with each other during transformation. The first method achieves this by first rotating the polygon by a predefined offset and then applying a macroscopic parameter adjustment to create a new pattern. If the new pattern is a line pattern the macroscopic parameter adjusted is the lateral radius of the circle in which the polygonal pattern is circumscribed. A further rotation is then performed to ensure a regular pattern; in the case of a transformation to a line the further rotation effectively adjusts the separation between the robots to equidistant.

The second method avoids collisions between robots by first shifting from a global frame of reference to a local reference frame, performing a discrete (Moebius) transformation along with path planning to take the robots to their positions in the new pattern and then finally shifting from the local to the global reference frame. Microscopic parameters adjustments occur within the global frame of reference while macroscopic parameter adjustments occur within the global frame of reference. The microscopic parameter adjustment includes the positions of the robots whereas the macroscopic parameters adjustments include for example the compactness of the pattern. The pattern resulting from the line to circle transformation is distorted since the robots aren't distributed evenly around the circle; this is a limitation of the computer modelling of the transformation since only a discrete set of point (the robot's positions) are used in the transformation.

The selection of the transformation tool impacts on the communication requirements for a swarm system. In the first method three broadcast message are required.

1 – the first is to effect the first rotation,

2 – to effect the pattern transformation and

3 – to effect the additional rotation.

These messages need only be a few bytes in length. In addition, each robot will only receive three short messages, none of which it will need to discard. In contrast, in the second method, a centralized global planner is required which in practical terms means offloading the planning to a high-performance workstation. Separate plans need to be generated for each individual robot and then each plan needs to be communicated to its target robot. This means that each robot receives many communications only one of which it is required to accept and each communication is a large packet of information because it contains a discretized plan for the robot. In summary, therefore, a mathematical framework can provide a basis for determining the communication costs for swarm system.

6 – Swarm-Array Computing

Networked Robotics Offers a unique viewpoint on some traditional problems in robotics, since it brings together networking and robotics technologies. It has also inspired a new way of looking at some problems outside robotics. For example, if a problem is solved using parallel algorithmic methods, the parallel components may be distributed across multiple computing nodes, and will require communication in order to coordinate if there are dependencies between the components. This model is very close to the distributed software model of networked robotics.

Parallel reduction algorithms are important in high performance computing (37)[26] . They are based on tree structures and one particular form of algorithms involves data flowing from the leaves of the towards the root. At each intermediate node the converging data input is transformed into a result that is passed forward to the next intermediate node. The interconnection of a node in the tree represents its dependences. For a binary tree, which is a popular data flow structure in high performance computing, the root node and each intermediate node has two input dependencies. For an N-ary tree the dependencies increase with N. this means that the complexity of communication and coordination between the needs also increases with N. When a parallel reduction algorithm is run on a high performance computer each node of the tree is scheduled onto a separate computing node. An important issue in high performance computing is that these computing nodes are susceptible to failures. The isolation of these failures is dealt with under fault tolerant computing. The conventional approach to addressing failures is checkpoint, which involves recording intermediate states of executing to which execution can be returned if one or more nodes on which the algorithms is executing fails. The traditional method for detecting failure has been administrator-based, whereby the human administrator of the system detects that the algorithms has stalled.

Chechpointing a general has two major drawbacks. Firstly, if there is a single point of failure then either all the nodes are restarted from scratch (a cold restart) or from a previous checkpoint (37) (38)[27] Decentralized checkpoint allows finer control of the restart. Secondly, if there are large number of nodes and dependencies the checkpoint overheads will be large (37)[28] These all reduce the efficiency of high performance computing systems.

The efficiency could be improved if in some way the algorithms itself could be self-managing. A simple definition of self-management in this context would be where if a node is about to fail the component of the algorithm can be moved off the node and the input and output dependencies re-established on another node. This would require the individual components to incorporate some level of agent-like intelligence whereby the condition of the computing node can be monitored and the component moved if failure is predicted.

One approach to incorporating intelligence is to map all of the parallel components of the task onto a set of agents such that the algorithm is essentially the payload of the agents. The set of agents then carry the payload onto the array of computing nodes. The array can be viewed as a landscape and the set of agents as essentially a robot swarm. The landscape comprises obstacles, which are nodes that have failed or are about to fail, and elevated terrain, where the height of the terrain reflects the load on the active nodes. The swarm can then move over this terrain to find an expanse where it can compute. Swarm pattern transformation methods (31) (32)[29] can be employed both to avoid obstacles and navigate narrow terrain, but also to compact the swarm into a small area if needed.

This approach provides a distributed alternative to one of the important yet centralized tasks in high performance computing, namely the scheduling of algorithm components to nodes. Further, if one of the nodes on which the swarm is located fails, a local adjustment can be made by the swarm agent relocating to a nearby part of the landscape and re-instantiating its dependencies. These two benefits of the swarm approach to high performance computing, which we refer to as swarm-array computing, offers the potential to improve the fault tolerance, and therefore increase the efficiency of high performance computing systems.

These concepts have been investigated practically through both a simulation and implementation (40) (41)[30] The implementation employed a computer cluster with 43 nodes. Message Passing Interface (MPI) (42) (43)[31] implementations, namely Open Message Passing Interface (OpenMPI) (44) (45)[32] and adaptive MPI (AMPI) (46)[33] built on Charm++(47)[34] were used as the middleware for the implementations. A parallel summation algorithm with fifteen nodes was implemented using both the classical approach and the swarm-array computing approach. The main conclusion of the implantation studies was that the swarm-array computing approach improved fault tolerance as measured by the mean time taken for reinstatement of the algorithm if a node failed. A further conclusion was that the existing middleware for high performance computing doesn't easily support the swarm-array computing concept. Notably, a number of workarounds were required to realize the implementation.

7 - manufacturing

improvements in American manufacturing competitiveness couldn't come at a better time. The global demand for manufactured goods is on the sill of the greatest expansion in history. Massive increases in demand are coming not

only for today's goods, but also for entirely new kinds of products currently in development.

Measured in money (not percentages, since it's the quantity of money that directly determines buying power), the world's GDP is forecasted to expand by nearly twice as much over the next 20 years as it did in the past 20. This means at least twice as much growth in demand for everything from cars and aircraft, to tractors and chemicals, to clothes and computers. All of these things will be fabricated, all of them will be more complex than in the past and, thus, all of them will migrate to more information-intensive production systems.

Add to this the emergence of entirely new types of products yet to be manufactured. The rise of the internal of things (IOT), which will on the back the existing internal-much as containerization rode an existing infrastructure-requires the manufacturing of trillions of sensors and "smart" devices. One of the biggest and perhaps most significant IOT markets will entail healthcare. In the near future, bio-electronics and transient electronics (think in terms usefully "consumable" computers). Will likely lead to an industry as big as today's $3trillion silicon-electronics sector.

In addition, researchers and developers are pioneering uses for new types of exotic materials, not least among them graphene and carbon fibers, as well as so-called metamaterials (materials that exhibit properties that don't exist naturally). And even though it still seems fanciful, dozens of firms, from start-up operations to industry giant airbus, are developing air taxis, which means that soon yet another new industry will emerge to manufacturing them. Finally, if the private sector space entrepreneurs are right, and commercial space travel becomes a real industry and not a niche, there will necessarily emerge yet more new manufacturing enterprises to produce all the specialized hardware.

With all of the above, the low-cost producer has an enormous advantage as always. For any manufacturer, competitiveness and growth are served best not by cheap labor but by superior technology. Fortunately, the manufacturing sector has long exhibited the power to put new tools to work once they become practical. The technologies surrounding robotics, in particular, are rapidly advancing for manufacturing applications. The same technologies are now also reaching a kind of tipping point for use in the service industries.

8 – The coming robotification of services

Venture-capital investment offers a window into the kinds of technology that will drive future productivity gains, here we see, in the CB Insights tracking of robot investments. That service-oriented – rather than industrial – applications dominate, with 80% of the $3 billion of venture capital in the past four years put to work on next-generation robots. Investors made bets on companies developing robots for retail, warehouse, delivery, laboratory, educational, surgical, hospital, rehab, safety, security, environmental monitoring and social applications. Clearly, innovators and investors think that services represent a great opportunity for success.

Infusing software into hardware-to make true cyber physical systems, such that they become functionally, invisibly and reliably part of the world of atoms-is challenging. Unlike the purely cyber world, the physical world has things like

inertia, friction, gravity and non-linear random events, all with serious safety implications. The real (as opposed to virtual) world cannot tolerate the equivalent of frozen screens, reboots, video jitter or iterations of software upgrades to clean up sloppy code rushed to market. But cyber physical technologies are improving rapidly, and we have already seen "first fission." But long before we see practical general-purpose robots, we will see commercially viable task-specific ones for applications across the service sectors.

9 – for any manufacturer, competitiveness and growth are served best not by cheap labor but by superior technology.

A proliferation of prototypes can be seen already, including some early commercial products for applications ranging from warehouse and delivery services, to firefighting and rescue work, to the pentagon's robotic "mule" program for carrying heavy gear for soldiers. The "mule" program has slowed, in large measure because such general-purpose machines remain both too expensive and too noisy in the field, the robot equivalent of the Model A has yet to be sold.

However, practical Model A's, if not Model T's, are already in use in homes, hospitals and warehouses, where comparatively light tasks and proximity to power sources make battery-powered robots viable. The more specific and narrow the task, the simpler the cyber physical challenges and the less expensive the machine. Six years ago, Amazon spent $700 million to acquire robot-maker Kiva for its wheeled, turtle-like, pallet-carrying warehouse robot, and Amazon has been sponsoring an annual contest to see whether robots can grab jumbled products from a bin and put them on a shelf.

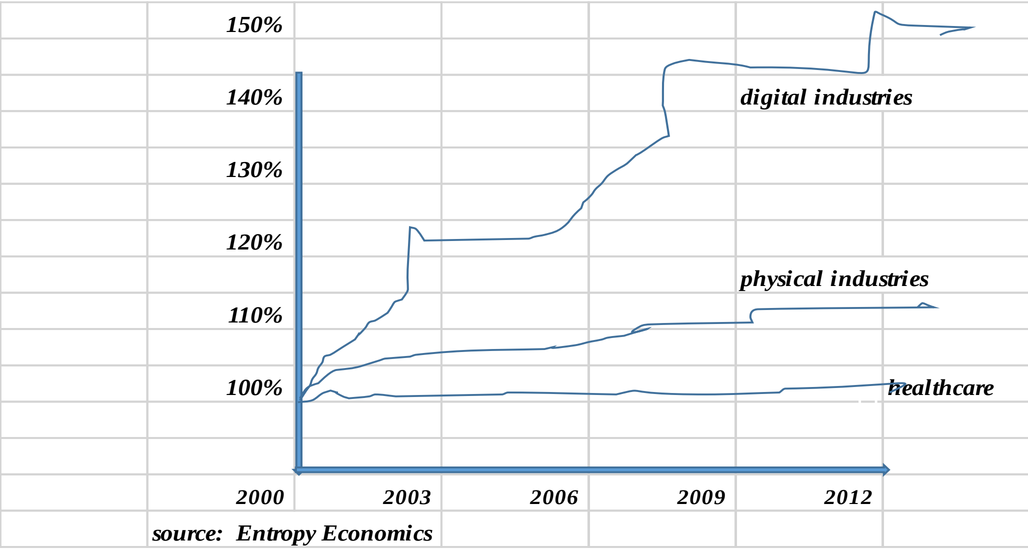
Other types of service-specific machines are starting to appear, still mostly prototypes but some commercially available. While surgical robots continue to be a significant early market, we see applications for service-related tasks in security, safety and environmental monitoring and assessment, general-purpose cleaning, hospital disinfection and self-driving wheelchairs.

A total of 10 million service robots are already sold annual around the world, though 80% are robotics vacuum cleaners, with most of the balance either robotic lawn mowers or light-duty drones. The forecast for 60 million low-cost service robots sold annually before 2030 anticipates engineers succeeding in conquering performance and cost challenges in a broad range of applications. But the inflection point is now in sight for a trend that began with history's first modern household washing machine a century ago. The emerging panoply of service robots will be directed at all applications, not just domestic chores and entertainment.

10 – better labor productivity can bring down soaring healthcare costs

Improve labor productivity is long overdue for many services, especially healthcare. As tech analyst Bret Swanson has usefully summarized, over the past 15 years, healthcare productivity- value added per labor-hour- has

remained stagnant, while productivity in physical industries has improved by about 15% and productivity in digital industries has improved by 50%.



The absence of real progress in service labor productivity is clearly visible in the net result. Consider the changes in cost of goods versus cost of services in America over the past 20 years. While the prices of childcare, education and especially, medical and hospital services have increased by as much as four times the rate of inflation, the real costs associated with the production of physical things (e.g., cars, computers, furniture and food) have either decreased dramatically or, at least, not outpaced inflation. That's the magic of productivity gains, which most service-centric activities have yet to experience.

It's an old maxim in economics; if you want more of somethings, make it cheaper. The inverse also applies; rising costs depress people's ability to acquire the desired product or service and collaterally depress the potential for (productive) employment growth in the industries providing those products and services.

Of course, educators and employers are eager to have access to people who are familiar with technology, but many of the skills they are seeking do not require a STEM degree.

digital twins can do more than bring efficiency and productivity to supply chains or machines; they promise radical improvements for complex systems or processes including, not least, for healthcare and medical procedures. In principle, with sufficiently granular information, a digital twin could predict a particular medication's impact down to the cellular level. While what has been termed the" virtual physiological human" remain aspirational, other service-related and manufacturing processes are already viable. adoption of this technology is in the early stages. At the beginning of 2018, only 4% of manufacturing companies has operational virtual twins, but almost 30% said they planned to start trials in the coming 12 months.

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