Robotics

Part 1. The Technology

In 1956, Joseph Engelberger (who would later be known as the **Father of Robotics**) met inventor George Devol at a cocktail party. They got to talking about George's latest invention—a mechanical arm—which Joseph proclaimed to be a robot. That triggered a series of events which resulted in the birth of the *Unimate #001, the world's first robot prototype*, in 1959.

By 1961, the Unimate 1900 series became the first mass produced robotic arm for factory automation, revolutionizing the global manufacturing industry.

Designed as *intelligent machines to help and assist humans in their day-to-day lives* and keep the public safe, the robots of today have come a long way since the Unimate.

Just as personal computers expanded our mental capabilities by transforming the way we process and use information, robots are designed to stretch our physical limits by carrying out tasks that require extraordinary strength, precision, and stamina.

Robots: A Mechanical Extension of Humans

In the field of healthcare, robotic surgery arms allow for less invasive surgery techniques to be carried out with unmatched precision and control. These innovative robotic-assisted systems allow surgeons to make small, precise incisions compared to conventional open surgeries that come with a higher risk of infections and complications besides longer recovery times.

Meanwhile, the continued advancement of AI, specifically its convergence with robotics, expands both our mental and physical capabilities at the same time.

Human-Robot Collaborations

Researchers at the University of Liverpool built a first-of-its-kind mobile robot scientist that has infinite patience, the ability to think in 10 dimensions, and works for 21.5 hours a day, pausing only to recharge its battery.

Measuring 1.75 meters tall, its human-like dimensions and physical reach allow it to roam around the laboratory, performing a wide range of tasks such as weighing out solids, dispensing liquids, removing air from the vessel, running the catalytic reaction, and quantifying the reaction products. So far, the robot has independently discovered a new catalyst six times more active, all on its own.

Operating in Hazardous & Extreme Environments

With robots, we are now able to operate in much more challenging environments, such as hazardous and extreme environments that wouldn't be safe for humans.

Thomas Frantz, Environmental Products Group Program Manager at PaR Systems, highlights the importance of robotics in munition disassembly. *"PaR is focused on handling munitions, such as leftover World War II nerve gas ordnance. The chemicals are decomposing and the materials are corroding,"* Frantz says. *"Robots pick up the munitions and place them in various process stations. Due to the fact that these old munitions are corroding, they are even more dangerous than is typical."*

A guest post by Innovate UK (the British government's innovation agency) sheds light on the need for AI-powered robots in applications such as mapping the sea bed. The article notes that while robots have been used in deep sea diving since the 1970s, there is a need for significant advancements in the technology to meet current demands, particularly in extreme environments.

The amount of unexploded ammunition that has accumulated on the sea floor creates a serious safety risk and needs to be disposed of before internet cables can be laid or offshore wind turbines can be built. Diving to such extreme depths and temperatures and handling these delicate operations call for intelligent robots that are able to make autonomous decisions and solve problems on their own.

Other common applications include robots carrying people from burning buildings, tunneling through collapsed rock falls to reach trapped miners, and rescuing skiers buried in an avalanche. Fire fighting, removing high-level nuclear contamination, reactor decommissioning—these are just a few areas where robots allow us to operate much more effectively than we would be able to on our own.

Part 2. The Implications

Industrial Manufacturing

The market for robots is tremendous, especially in industrial manufacturing. A report by Mordor Intelligence projects that *the industrial robotics market, valued at $20.24 billion in 2019, will more than double to reach $42.34 billion by 2025.*

The largest customer of industrial manufacturing robots is the automotive industry, which accounts for over half of all global sales. The increasing adoption of automation in automotive manufacturing and the growth of AI applications in smart factory systems are primary factors driving the demand for industrial robots in the automotive sector.

As illustrated in the chart below, the operational stock of multipurpose industrial robots worldwide has been growing steadily year-on-year over the last 5 years, increasing from 1.6 million in 2015 to 2.7 million in 2019.

Nanobots

The word “nano” comes from the Greek word for “dwarf”. A nanometer is one billionth of a meter or 10^{-9} meters which is approximately the width of 10 atoms.

Nanobots are *miniature robotic machines at or near the scale of a nanometer*. Designed to perform specific tasks on a near atomic level, nanobots are expected to revolutionize the technology for medical diagnosis and drug delivery.

While nanobots may be synthetic or biological, a hybrid device possessing both biological and robotic features will likely be the most effective. The ideal nanobot or nanite will have mobility, the ability to process information or to be programmed, have a power supply, *and* be able to self-replicate. Scientists envision the manufacture of such a nanite in approximately 25 years.

The earliest adoption of nanobots will be in nanomedicine, namely in tissue repair, early diagnosis, targeted drug delivery for cancer, and monitoring diabetes.

Because of their microscopic size, nanobots interact on the same level as bacteria and viruses, allowing them to build with the very particles of our bodies: the atoms and molecules. They can be equipped with all sorts of tools such as a camera to monitor and capture detailed information about the human body, and nano laser and nano chemical to clean infected areas. They can also be controlled internally and externally to perform a variety of functions, e.g. disposing dead cells or tissues at a wound and helping to regrow a tissue so it heals cleanly and quickly without leaving a nasty scar.

Recent developments in nanobots include the successful treatment of cancerous tumours in mice and French startup Eligo Bioscience's biological nanobots designed to combat antibiotic resistance. Eligo's nanobots are programmed to target disease-causing bacteria with sniper-like precision while leaving the good bacteria intact, which is key to preventing antibiotic resistance.

Swarm Robotics

Inspired by the advantageous cooperative structures and behaviours in animals and living organisms such as bees, birds, and fish, swarm robotics involve multiple robots—homogeneous or heterogeneous—forming a swarm of robots by interacting with each other and reacting to the environment autonomously.

Designed to cooperate without any central control, these robots act according to simple and local behaviour, through which emerges a collective behaviour to solve complex tasks. Robot swarms are adaptable, robust, and able to scale easily.

Since nanobots are so tiny, swarms of them will be necessary to perform most tasks, though industrial swarm robotics will involve much larger robots.

Industrial Applications

In agriculture, swarm robotics in the form of agricultural UGVs (unmanned ground vehicles) are used to meet the increasing demand for food production. Their diverse tasks include planting, applying fertilizer, eliminating weeds and insects, irrigation, and harvesting. They are cloud-controlled and work cooperatively with each other according to a centrally planned schedule.

Swarm robotic boats or USVs (unmanned surface vehicles) are used in aquatic missions such as measuring and monitoring water quality, where the boats perform centrally planned collective exploration and interact with the human operator.

Other aquatic applications include service and maintenance of large ships where swarms made of different cooperating UxV (unmanned vehicles)—UGV, UAV, UUV (ground, air, underwater)—are deployed for multi-robot visual and acoustic inspection of the hull structure, detection of corrosion patches, and surface cleaning. These swarms are also used for corrosion prevention in offshore installations, monitoring of chemical pollution, and tracking of plumes.

In military applications, swarm robotics allow for autonomous operation of US Navy boats whereby these USVs (unmanned surface vehicles) choose their own routes to intercept enemy vessels as a swarm and to escort and protect naval assets. The technology is also used for sea and land border surveillance, environmental monitoring, infrastructure inspection, and national security.

Consumer Robots

While seemingly mundane in comparison, consumer robots—particularly cleaning robots such as robotic vacuum cleaners—continue to see steady growth in consumer adoption. The global market for robotic vacuum cleaners has recorded a constant upward trajectory from $0.81 billion in 2015 to $2.54 billion in 2020, and is projected to hit $4.98 billion in 2025.

The most well-known example being Roomba, the autonomous robotic vacuum cleaner by iRobot introduced in 2002. Designed to autonomously navigate the floor area of a home and clean it, Roomba's sensors detect the presence of obstacles, dirty spots on the floor, and can sense steep drops to prevent it from falling down stairs.

Newer high-end models also feature a camera which works in conjunction with onboard mapping and navigation software to systematically cover the whole floor area, move from room to room, and find recharging bases and beacons.

There's also Landroid, the first fully customizable robot mower that autonomously decides how to mow your lawn. Using cloud computing to combine data such as rainfall, temperature, sunlight, and weather forecast, its customized algorithm fine-tunes mowing cycles according to the actual growth rate of the grass to deliver the perfectly-mown lawn every time.

Looking ahead, consumer robots will play an instrumental role in elder care as countries around the world grapple with providing healthcare for a growing population of elderly people.

Japan has one of the highest populations of senior citizens; 20% of their current population is 65 years and above, and the country is expected to face a shortage of 1 million caregivers by 2025. To address the problem, Japanese companies have started developing Carebots—robots designed specifically to assist elderly people—which have been allocated a third of the Japanese government's budget.

Examples of these Carebots include Honda's Asimo, an autonomous, humanoid robot created to help the elderly by getting them food or turning off lights. Robobear, a nursing robot, helps transfer seniors from the bed to a wheelchair by physically lifting them.

Robots are also ideal for use in security and surveillance. Being machines, they can run 24 hours a day, have infinite patience, see in the dark with infrared cameras, and additionally, be able to patrol with video capture compared to current static CCTV cameras.

Collaborative Robotics (Cobots)

Unlike traditional industrial robot applications where robots are isolated from human contact, collaborative robots (aka cobots) are meant for direct human-robot interaction within a shared space or where humans and robots work in close proximity.

Applications include information robots in public spaces (service robots), logistics robots that transport objects within a building, and industrial robots that assist in unergonomic tasks such as moving heavy parts, machine feeding or assembly operations.

As observed in the report by Mordor Intelligence, Industry 4.0 (the automation of traditional manufacturing and industrial practices using modern smart technology) has fueled the development of new technologies such as collaborative robots and AI-enabled robots to streamline processes, increase efficiency, and eliminate errors.

This further underscores the immense benefits of human-robot collaborations, such as the previously cited example of researchers collaborating with their robot scientist for discovery of new drugs. By combining AI with robotics, we'll be able to think and function on a whole new level.

What does this mean for the future?

Part 3. The Future

Since Joseph Engelberger and George Devol's Unimate #001 in 1959, we've seen robots go from being human-operated mechanical contraptions to being pre-programmed to carry out specific tasks, and now, with AI programming, we're seeing the next generation of intelligent robots take shape.

Each of these robots have a role to play. Human-operated robotic surgery arms allow surgeons to offer vastly superior treatment options while pre-programmed robots assist in all kinds of tasks from industrial assembly to lifting heavy loads and filling beakers in a lab.

In households, intelligent robots such as Roomba and Landroid autonomously vacuum floors and mow lawns without any human supervision, and that's just skimming the surface of what AI-powered robots are capable of.

The immense potential for revolutionary breakthroughs in AI-powered robotics can't be emphasized enough. We've seen how robotics technology enhanced with swarm AI can mobilize swarms of intelligent robots to increase agriculture production, monitor chemical pollution in the ocean, protect naval assets, and provide sea and land border surveillance.

Beyond that, the *convergence of robotics with other exponential technologies* promises equally exciting developments in a growing number of industries.

Internet of Things + Robotics

Take the Internet of Things (IoT) with robots added into the mix.

The Internet of Robotic Things (IoRT) is defined as *"a concept in which intelligent devices can monitor the events happening around them, fuse their sensor data, make use of local and distributed intelligence to decide on courses of action and then behave to manipulate or control objects in the physical world."*

Unlike the IoT where connected devices are only able to collect, process, and act on the data in the cyber environment, with the IoRT, robots have the added advantage of being able to manipulate or control physical objects and move in the physical world (if they're programmed to do so).

IoRT examples include parking lot robots—where robotic devices check corporate parking lots for unauthorized cars and issue alerts, industrial cleaning robots, and notably, Amazon Robotics' warehouse where mobile robots whizz around transporting packages to designated points in an intricate system that involves pausing for one another at intersections to avoid accidents.

A report by Research and Markets projects the Internet of Robotic Things market to be valued at $21.44 billion by 2022, growing at a CAGR of 29.7% between 2016 and 2022,

with collaborative industrial robots expected to grow at the highest rate in the IoRT market.

If you've not seen collaborative robots (cobots) in action, there's Miso Robotics' Flippy: the world's first autonomous robotic kitchen assistant that can learn from its surroundings and acquire new skills over time. Flippy is a burger-flipping robot that can work on a grill or fryer in compliance with OSHA and food-safety standards, and run for up to 100,000 hours of continuous uptime. Flippy can work alongside people in any commercial kitchen.

There's also a robot bartender in Prague that serves drinks ordered through a phone app and performs little dances when it's bored—how's that for added entertainment?

Coffee lovers might get a kick out of Café X: a sleek robotic coffee bar where you can get a coffee made by a Mitsubishi cobot.

Self-Driving Cars, Air Taxis, and the Hyperloop

Another new market to have emerged from the convergence of robotics and transportation: **autonomous vehicles**.

The global autonomous vehicle market is expected to grow from $54.23 billion in 2019 to a whopping $556.67 billion by 2026, according to a recent report by Allied Market Research. These autonomous vehicles include ridehail, rideshare, self-driving trucks, self-driving buses, and more.

Meanwhile, a report by Fortune Business Insights projects the autonomous car segment to reach $1.33 billion by 2027. In comparison, the global air taxi market is predicted to reach $6.63 billion by 2030, according to Allied Market Research.

Leading the charge in disrupting the urban transportation landscape, Uber Elevate—a shared air taxi service by Uber—is expected to launch in 2023. The company plans to launch fleets of small, electric VTOL (vertical takeoff and landing) aircraft in Dallas, Los Angeles, and Melbourne, their first international market.

Back on the ground, Waymo launched the first fully autonomous driverless taxi service, Waymo One, to the general public in Phoenix, Arizona in October 2020.

While the Hyperloop remains a futuristic concept that's still years away from being commercially viable, Virgin Hyperloop's recent human test of the technology—the first of its kind—proves that the technology is slowly but surely progressing in the right direction. The two test volunteers, wearing casual street clothes, were whisked in a pod that was levitated by magnets inside a vacuum tube to 107 m.p.h. in 6.25 seconds!

Unlike trains which operate on fixed schedules, hyperloop pods are designed to function like smart elevators, using artificial intelligence to adjust destinations, the number of pods travelling in a convoy, and departure times based on demand.

The visionary system is expected to transport people and objects at airline or hypersonic speeds while being far more energy efficient compared to existing high-speed rail systems. Virgin's company executives believe the system could be commercialized by the end of the decade.

Nanobots: Key to Advancing Longevity Research

"One hundred will be the new 60."

So proclaims Peter Diamandis, a space, technology, aeronautics and medicine pioneer. He asserts that *"The average human health span will increase by 10+ years this decade." (cited in the Financial Post)*

Artificial intelligence, cloud computing, networks, sensors, robotics, massive datasets, biotechnology and nanotechnology: all these technologies are converging to focus on prolonging the human lifespan, specifically by advancing longevity research.

Nanobots are being programmed to repair aged or diseased cells, provide targeted delivery of drugs, detect the presence of cancer cells, combat antibiotic resistance, and much more.

The global nanomedicine market is anticipated to reach $350.8 billion by 2025, according to a report by Grand View Research, Inc. Cancer being one of the major causes of mortality and morbidity worldwide, demand for nanomedicine in oncology is expected to be one of the key drivers for market growth.

What Does a Future with Robots Look Like?

While COVID-19 has completely transformed the way we live, work, and play, it might also have helped the public become more receptive towards robots as these machines step in to take over high-exposure tasks such as sanitizing warehouses and hospitals, ferrying test samples to laboratories, and serving as telemedicine avatars.

In their book entitled *"What to Expect When You're Expecting Robots"*, engineers Julie Shah and Laura Major paint a future where robots *"will no longer work for us, but with us. They will be less like tools, programmed to carry out specific tasks in controlled environments, as factory automatons and domestic Roombas have been, and more like partners, interacting with and working among people in the more complex and chaotic real world."*

From drones deployed in combat situations throughout the Middle East to entire classes of robots developed for battlefield usage, military forces around the world are moving towards a future with Army robots. Robotic tanks, artillery vehicles, and reconnaissance vehicles: these are just a few examples of what armies of the future could look like.

Co-existing with robots might take some getting used to, but they play a pivotal role in shaping a far superior civilization with enhanced intelligence and social structures, one that promises healthier, stronger, and richer societies all over the world.