

Mobile Robots

Pamala Burkhart

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Email: info@wtbooks.com

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Chapter- 1

Mobile Robots

A **mobile robot** is an automatic machine that is capable of movement in a given environment.

Overview

Mobile robots have the capability to move around in their environment and are not fixed to one physical location. In contrast, industrial robots usually consist of a jointed arm (multi-linked manipulator) and gripper assembly (or end effector) that is attached to a fixed surface.

Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research. Mobile robots are also found in industry, military and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum

Classification

Mobile robots may be classified by:

- The environment in which they travel:
 - Land or home robots. They are most commonly wheeled, but also include legged robots with two or more legs (humanoid, or resembling animals or insects).
 - Aerial robots are usually referred to as unmanned aerial vehicles (UAVs)
 - Underwater robots are usually called autonomous underwater vehicles (AUVs)
- The device they use to move, mainly:
 - Legged robot : human-like legs (i.e. an android) or animal-like legs.
 - Wheeled robot.
 - Tracks .

Mobile robot navigation

There are many types of mobile robot navigation:

Manual remote or tele-op

A manually tele-op'd robot is totally under control of a driver with a joystick or other control device. The device may be plugged directly into the robot, may be a wireless joystick, or may be an accessory to a wireless computer or other controller. A tele-op'd robot is typically used to keep the operator out of harm's way. Examples of manual remote robots include Robotics Design's ANATROLLER ARI-100 and ARI-50, Foster-Miller's Talon, iRobot's PackBot, and KumoTek's MK-705 Roosterbot.

Guarded tele-op

A guarded tele-op robot has the ability to sense and avoid obstacles but will otherwise navigate as driven, like a robot under manual tele-op. Few if any mobile robots offer only guarded tele-op.

Line-following robot

Some of the earliest Automated Guided Vehicles (AGVs) were line following mobile robots. They might follow a visual line painted or embedded in the floor or ceiling or an electrical wire in the floor. Most of these robots operated a simple "keep the line in the center sensor" algorithm. They could not circumnavigate obstacles; they just stopped and waited when something blocked their path. Many examples of such vehicles are still sold, by Transbotics, FMC, Egemin, HK Systems and many other companies.

Autonomously randomized robot

Autonomous robots with random motion basically bounce off walls, whether those walls are sensed with physical bumpers like the Roomba cleaners or with electronic sensors like the Friendly Robotics lawn mower. The simple algorithm of bump and turn 30 degrees leads eventually to coverage of most or all of a floor or yard surface.

Autonomously guided robot



Robot developers use ready-made autonomous bases and software to design robot applications quickly. Shells shaped like people or cartoon characters may cover the base to disguise it.

An autonomously guided robot knows at least some information about where it is and how to reach various goals and or waypoints along the way. "Localization" or knowledge of its current location, is calculated by one or more means, using sensors such as motor encoders, vision, Stereopsis, lasers and global positioning systems. Positioning systems often use triangulation, relative position and/or Monte-Carlo/Markov localization to determine the location and orientation of the platform, from which it can plan a path to its next waypoint or goal. It can gather sensor readings that are time- and location-stamped, so that a hospital, for instance, can know exactly when and where radiation levels exceeded permissible levels. Such robots are often part of the wireless enterprise network, interfaced with other sensing and control systems in the building. For instance, the PatrolBot security robot responds to alarms, operates elevators and notifies the command center when an incident arises. Other autonomously guided robots include the SpeciMinder and the Tug delivery robots for hospital labs, though the latter actually has people at the ready to drive the robot remotely when its autonomy fails. The Tug sends a letter to its tech support person, who then takes the helm and steers it over the Internet by looking through a camera low in the base of the robot.

Sliding autonomy

More capable robots combine multiple levels of navigation under a system called sliding autonomy. Most autonomously guided robots, such as the HelpMate hospital robot, also offer a manual mode. The Motivity autonomous robot operating system, which is used in the ADAM, PatrolBot, SpeciMinder, MapperBot and a number of other robots, offers full sliding autonomy, from manual to guarded to autonomous modes.

History

1939–1945

During World War II the first mobile robots emerged as a result of technical advances on a number of relatively new research fields like computer science and cybernetics. They were mostly flying bombs. Examples are smart bombs that only detonate within a certain range of the target, the use of guiding systems and radar control. The V1 and V2 rockets had a crude 'autopilot' and automatic detonation systems. They were the predecessors of modern cruise missiles.

1948–1949

W. Grey Walter builds Elmer and Elsie, two autonomous robots that looked like turtles. Officially they were called Machina Speculatrix because these robots liked to explore their environment. Elmer and Elsie were equipped with a light sensor, if they found a light source they would move towards it, avoiding or moving obstacles on their way. These robots demonstrated that complex behaviour could arise from a simple design, Elmer and Elsie only had the equivalent of two nerve cells.

1961–1963

The Johns Hopkins University develops 'Beast'. Beast used a sonar to move around. When its batteries ran low it would find a power socket and plug itself in.

1969

Mowbot was the very first robot that would automatically mow the lawn.

1970

The Stanford Cart line follower was a mobile robot that was able to follow a white line, using a camera to see. It was radio linked to a large mainframe that made the calculations. At about the same time (1966–1972) the Stanford Research Institute is building and doing research on Shakey the Robot, a robot named after its jerky motion. Shakey had a camera, a rangefinder, bump sensors and a radio link. Shakey was the first robot that could reason about its actions. This means that Shakey could be given very general commands, and that the robot would figure out the necessary steps to accomplish the given task.

The Soviet Union explores the surface of the Moon with Lunokhod 1, a lunar rover.

1976

In its Viking program the NASA sends two unmanned spacecrafts to Mars.

1980

The interest of the public in robots rises, resulting in robots that could be purchased for home use. These robots served entertainment or educational purposes. Examples include the RB5X, which still exists today and the HERO series.

The Stanford Cart is now able to navigate its way through obstacle courses and make maps of its environment.

Early 1980s

The team of Ernst Dickmanns at Bundeswehr University of Munich builds the first robot cars, driving up to 55 mph on empty streets.

1987

Hughes Research Laboratories demonstrates the first cross-country map and sensor-based autonomous operation of a robotic vehicle.

1989

Mark Tilden invents BEAM robotics.

1990s

Joseph Engelberger, father of the industrial robotic arm, works with colleagues to design the first commercially available autonomous mobile hospital robots, sold by Helpmate. The US Department of Defense funds the MDARS-I project, based on the Cybermotion indoor security robot.

1991

Edo. Franzi, André Guignard and Francesco Mondada developed Khepera, an autonomous small mobile robot intended for research activities. The project was supported by the LAMI-EPFL lab.

1993–1994

Dante I and Dante II were developed by Carnegie Mellon University. Both were walking robots used to explore live volcanoes.

1994

With guests onboard, the twin robot vehicles VaMP and VITA-2 of Daimler-Benz and Ernst Dickmanns of UniBwM drive more than one thousand kilometers on a Paris three-lane highway in standard heavy traffic at speeds up to 130 km/h. They demonstrate autonomous driving in free lanes, convoy driving, and lane changes left and right with autonomous passing of other cars.

1995

Semi-autonomous ALVINN steered a car coast-to-coast under computer control for all but about 50 of the 2850 miles. Throttle and brakes, however, were controlled by a human driver.

1995

In the same year, one of Ernst Dickmanns' robot cars (with robot-controlled throttle and brakes) drove more than 1000 miles from Munich to Copenhagen and back, in traffic, at up to 120 mph, occasionally executing maneuvers to pass other cars (only in a few critical situations a safety driver took over). Active vision was used to deal with rapidly changing street scenes.

1995

The Pioneer programmable mobile robot becomes commercially available at an affordable price, enabling a widespread increase in robotics research and university study over the next decade as mobile robotics becomes a standard part of the university curriculum.

1996–1997

NASA sends the Mars Pathfinder with its rover Sojourner to Mars. The rover explores the surface, commanded from earth. Sojourner was equipped with a hazard avoidance system. This enabled Sojourner to autonomously find its way through unknown martian terrain.

1999

Sony introduces Aibo, a robotic dog capable of seeing, walking and interacting with its environment. The PackBot remote-controlled military mobile robot is introduced.

2001

Start of the Swarm-bots project. Swarm bots resemble insect colonies. Typically they consist of a large number of individual simple robots, that can interact with each other and together perform complex tasks.

2002

Appears Roomba, a domestic autonomous mobile robot that cleans the floor.

2003

Axxon Robotics purchases Intellibot, manufacturer of a line of commercial robots that scrub, vacuum, and sweep floors in hospitals, office buildings and other commercial buildings. Floor care robots from Intellibot Robotics LLC operate completely autonomously, mapping their environment and using an array of sensors for navigation and obstacle avoidance.

2004

Robosapien, a biomorphic toy robot designed by Mark Tilden is commercially available. In 'The Centibots Project' 100 autonomous robots work together to make a map of an unknown environment and search for objects within the environment. In the first DARPA Grand Challenge competition, fully autonomous vehicles compete against each other on a desert course.

2005

Boston Dynamics creates a quadruped robot intended to carry heavy loads across terrain too rough for vehicles.

2006

Sony stops making Aibo and HelpMate halts production, but a lower-cost PatrolBot customizable autonomous service robot system becomes available as mobile robots continue the struggle to become commercially viable. The US Department of Defense drops the MDARS-I project, but funds MDARS-E, an autonomous field robot. TALON-Sword, the first commercially available robot with grenade launcher and other integrated weapons options, is released. . Honda's Asimo learns to run and climb stairs.

2007

History is made with the DARPA Urban Grand Challenge, with six vehicles autonomously completing a complex course involving manned vehicles and obstacles. Kiva Systems clever robots proliferate in distribution operations; these smart shelving units sort themselves according to the popularity of their contents. The Tug becomes a popular means for hospitals to move large cabinets of stock from place to place, while the Speci-Minder with Motivity begins carrying blood and other patient samples from nurses' stations to various labs. Seekur, the first widely available, non-military outdoor service robot, pulls a 3-ton vehicle across a parking lot, drives autonomously indoors and begins learning how to navigate itself outside. Meanwhile, PatrolBot learns to follow people and detect doors that are ajar.

2008

Boston Dynamics released video footage of a new generation BigDog able to walk on icy terrain and recover its balance when kicked from the side.

Chapter- 2

Aerobot

An **aerobot** is an aerial robot, usually used in the context of an unmanned space probe or unmanned aerial vehicle.

While work has been done since the 1960s on robot "rovers" to explore the Moon and other worlds in the Solar system, such machines have limitations. They tend to be expensive and have limited range, and due to the communications time lags over interplanetary distances, they have to be smart enough to navigate without disabling themselves.

For planets with atmospheres of any substance, however, there is an alternative: an autonomous flying robot, or "aerobot" Most aerobot concepts are based on aerostats, primarily balloons, but occasionally airships. Flying above obstructions in the winds, a balloon could explore large regions of a planet in great detail for relatively low cost. Airplanes for planetary exploration have also been proposed.

Basics of balloons

While the notion of sending a balloon to another planet sounds strange at first, balloons have a number of advantages for planetary exploration. They can be made light in weight and are potentially relatively inexpensive. They can cover a great deal of ground, and their view from a height gives them the ability to examine wide swathes of terrain with far more detail than would be available from an orbiting satellite. For exploratory missions, their relative lack of directional control is not a major obstacle as there is generally no need to direct them to a specific location.

Balloon designs for possible planetary missions have involved a few unusual concepts. One is the solar, or infrared (IR) Montgolfiere. This is a hot-air balloon where the envelope is made from a material that traps heat from sunlight, or from heat radiated from a planetary surface. Black is the best color for absorbing heat, but other factors are involved and the material may not necessarily be black.

Solar Montgolfieres have several advantages for planetary exploration, as they can be easier to deploy than a light gas balloon, do not necessarily require a tank of light gas for

inflation, and are relatively forgiving of small leaks. They do have the disadvantage that they are only aloft during daylight hours.

The other is a "reversible fluid" balloon. This type of balloon consists of an envelope connected to a reservoir, with the reservoir containing a fluid that is easily vaporized. The balloon can be made to rise by vaporizing the fluid into gas, and can be made to sink by condensing the gas back into fluid. There are a number of different ways of implementing this scheme, but the physical principle is the same in all cases.

A balloon designed for planetary exploration will carry a small gondola containing an instrument payload. The gondola will also carry power, control, and communications subsystems. Due to weight and power supply constraints, the communications subsystem will generally be small and low power, and interplanetary communications will be performed through an orbiting planetary probe acting as a relay.

A solar Montgolfiere will sink at night, and will have a guide rope attached to the bottom of the gondola that will curl up on the ground and anchor the balloon during the darkness hours. The guide rope will be made of low friction materials to keep it from catching or tangling on ground features.

Alternatively, a balloon may carry a thicker instrumented "snake" in place of the gondola and guiderope, combining the functions of the two. This is a convenient scheme for making direct surface measurements.

A balloon could also be anchored to stay in one place to make atmospheric observations. Such a static balloon is known as an "aerostat".

One of the trickier aspects of planetary balloon operations is inserting them into operation. Typically, the balloon enters the planetary atmosphere in an "aeroshell", a heat shield in the shape of a flattened cone. After atmospheric entry, a parachute will extract the balloon assembly from the aeroshell, which falls away. The balloon assembly then deploys and inflates.

Once operational, the aerobot will be largely on its own and will have to conduct its mission autonomously, accepting only general commands over its long link to Earth. The aerobot will have to navigate in three dimensions, acquire and store science data, perform flight control by varying its altitude, and possibly make landings at specific sites to provide close-up investigation.

The Venus Vega balloons

The first balloon was inserted into the atmosphere of Venus on 11 June 1985, followed by the second balloon on 15 June 1985. The first balloon failed after only 56 minutes, but the second operated for a little under two Earth days until its batteries ran down.

The Venus Vega balloons were the idea of Jacques Blamont, chief scientist for CNES and the father of planetary balloon exploration. He energetically promoted the concept and enlisted international support for the small project.

The scientific results of the Venus VEGA probes were modest. More importantly, the clever and simple experiment demonstrated the validity of using balloons for planetary exploration.

The Mars aerobot effort

After the success of the Venus VEGA balloons, Blamont focused on a more ambitious balloon mission to Mars, to be carried on a Soviet space probe.

The atmospheric pressure on Mars is about 150 times less than that of Earth. In such a thin atmosphere, a balloon with a volume of 5,000 to 10,000 cubic meters (178,500 to 357,000 cubic feet) could carry a payload of 20 kilograms (44 pounds), while a balloon with a volume of 100,000 cubic meters (3,600,000 cubic feet) could carry 200 kilograms (440 pounds).

The French had already conducted extensive experiments with solar Montgolfieres, performing over 30 flights from the late 1970s into the early 1990s. The Montgolfieres flew at an altitude of 35 kilometers, where the atmosphere was as thin and cold as it would be on Mars, and one spent 69 days aloft, circling the Earth twice.

Early concepts for the Mars balloon featured a "dual balloon" system, with a sealed hydrogen or helium-filled balloon tethered to a solar Montgolfiere. The light-gas balloon was designed to keep the Montgolfiere off the ground at night. During the day, the Sun would heat up the Montgolfiere, causing the balloon assembly to rise.

Eventually, the group decided on a cylindrical sealed helium balloon made of aluminized PET film, and with a volume of 5,500 cubic meters (196,000 cubic feet). The balloon would rise when heated during the day and sink as it cooled at night.

Total mass of the balloon assembly was 65 kilograms (143 pounds), with a 15 kilogram (33 pound) gondola and a 13.5 kilogram (30 pound) instrumented guiderope. The balloon was expected to operate for ten days. Unfortunately, although considerable development work was performed on the balloon and its subsystems, Russian financial difficulties pushed the Mars probe out from 1992, then to 1994, and then to 1996. The Mars balloon was dropped from the project due to cost, and the probe was lost on launch in 1996 anyway.

JPL aerobot experiments

By this time, the Jet Propulsion Laboratory (JPL) of the US National Aeronautics and Space Administration (NASA) had become interested in the idea of planetary aerobots, and in fact a team under Jim Cutts of JPL had been working on concepts for planetary

aerobots for several years, as well as performing experiments to validate aerobot technology.

The first such experiments focused on a series of reversible-fluid balloons, under the project name ALICE, for "Altitude Control Experiment". The first such balloon, ALICE 1, flew in 1993, with other flights through ALICE 8 in 1997.

Related work included the characterization of materials for a Venus balloon envelope, and two balloon flights in 1996 to test instrument payloads under the name BARBE, for "Balloon Assisted Radiation Budget Equipment".

By 1996, JPL was working on a full-fledged aerobot experiment named PAT, for "Planetary Aerobot Testbed", which was intended to demonstrate a complete planetary aerobot through flights into Earth's atmosphere. PAT concepts envisioned a reversible-fluid balloon with a 10-kilogram payload that would include navigation and camera systems, and eventually would operate under autonomous control. The project turned out to be too ambitious, and was cancelled in 1997.

JPL continued to work on a more focused, low-cost experiments to lead to a Mars aerobot, under the name MABVAP, for "Mars Aerobot Validation Program". MABVAP experiments included drops of balloon systems from hot-air balloons and helicopters to validate the tricky deployment phase of a planetary aerobot mission, and development of envelopes for superpressure balloons with materials and structures suited to a long-duration Mars mission.

JPL also provided a set of atmospheric and navigation sensors for the Solo Spirit round-the-world manned balloon flights, both to support the balloon missions and to validate technologies for planetary aerobots.

JPL aerobot mission concepts

While these tests and experiments were going on, JPL performed a number of speculative studies for planetary aerobot missions to Mars, Venus, Saturn's moon Titan, and the outer planets.

Mars

JPL's MABVAP technology experiments are intended to lead to an actual Mars aerobot mission, named MABTEX, for "Mars Aerobot Technology Experiment". As its name implies, MABTEX is primarily intended to be an operational technology experiment as a precursor to a more ambitious efforts. MABTEX is currently envisioned as a small superpressure balloon, carried to Mars on a "microprobe" weighing no more than 40 kilograms (88 lb). Once inserted, the operational balloon would have a total mass of no more than 10 kilograms (22 lb) and would remain operational for a week. The small gondola would have navigational and control electronics, along with a stereo imaging system, as well as a spectrometer and magnetometer.

Current plans envision a follow-on to MABTEX as a much more sophisticated aerobot named MGA, for "Mars Geoscience Aerobot". Current design concepts for MGA envision a superpressure balloon system very much like that of MABTEX, but much larger. MGA would carry a payload ten times larger than that of MABTEX, and would remain aloft for up to three months, circling Mars more than 25 times and covering over 500,000 kilometres (310,000 mi). The payload would include sophisticated equipment, such as an ultrahigh resolution stereo imager, along with oblique imaging capabilities; a radar sounder to search for subsurface water; an infrared spectroscopy system to search for important minerals; a magnetometer; and weather and atmospheric instruments. MABTEX might be followed in turn by a small solar-powered blimp named MASEPA, for "Mars Solar Electric Propelled Aerobot".

Venus

JPL has also pursued similar studies on Venus aerobots. A Venus Aerobot Technology Experiment (VEBTEX) has been considered as a technology validation experiment, but the focus appears to have been more on full operational missions. One mission concept, the Venus Aerobot Multisonde (VAMS), envisions an aerobot operating at altitudes above 50 kilometres (31 mi) that would drop surface probes, or "sondes", onto specific surface targets. The balloon would then relay information from the sondes directly to Earth, and would also collect planetary magnetic field data and other information. VAMS would require no fundamentally new technology, and may be appropriate for a NASA low-cost Discovery planetary science mission.

Significant work has been performed on a more ambitious concept, the Venus Geoscience Aerobot (VGA). Designs for the VGA envision a relatively large reversible-fluid balloon, filled with helium and water, that could descend to the surface of Venus to sample surface sites, and then rise again to high altitudes and cool off.

Developing an aerobot that can withstand the high pressures and temperatures (up to 480 degrees Celsius, or almost 900 degrees Fahrenheit) on the surface of Venus, as well as passage through sulfuric acid clouds, will require new technologies. VGA is not expected to be ready until late in the next decade. Prototype balloon envelopes have been fabricated from polybenzoxazole, a polymer that exhibits high strength, resistance to heat, and low leakage for light gases. A gold coating is applied to allow the polymer film to resist corrosion from acid clouds.

Work has also been done on a VGA gondola weighing about 30 kilograms (66 lb). In this design, most instruments are contained in a spherical pressure vessel with an outer shell of titanium and an inner shell of stainless steel. The vessel contains a solid-state camera and other instruments, as well as communications and flight control systems. The vessel is designed to tolerate pressures of up to a hundred atmospheres and maintain internal temperatures below 30 °C (86 °F) even on the surface of Venus. The vessel is set at the bottom of a hexagonal "basket" of solar panels that in turn provide tether connections to the balloon system above, and is surrounded by a ring of pipes acting as a heat exchanger.

An S-band communications antenna is mounted on the rim of the basket, and a radar antenna for surface studies extends out of the vessel on a mast.

Titan

Titan, the largest moon of Saturn, is an attractive target for aerobot exploration, as it has a nitrogen atmosphere twice as dense as that of Earth's that contains a smog of organic photochemicals, hiding the moon's surface from view by visual sensors. An aerobot would be able to penetrate this haze to study the moon's mysterious surface and search for complex organic molecules. NASA has outlined a number of different aerobot mission concepts for Titan, under the general name of Titan Biologic Explorer.

One concept, known as the Titan Aerobot Multisite mission, involves a reversible-fluid balloon filled with argon that could descend from high altitude to the surface of the moon, perform measurements, and then rise again to high altitude to perform measurements and move to a different site. Another concept, the Titan Aerobot Singlesite mission, would use a superpressure balloon that would select a single site, vent much of its gas, and then survey that site in detail.

An ingenious variation on this scheme, the Titan Aeroover, combines aerobot and rover. This vehicle features a triangular frame that connects three balloons, each about two meters (6.6 ft) in diameter. After entry into Titan's atmosphere, the aeroover would float until it found an interesting site, then vent helium to descend to the surface. The three balloons would then serve as floats or wheels as necessary. JPL has built a simple prototype that looks three beachballs on a tubular frame.

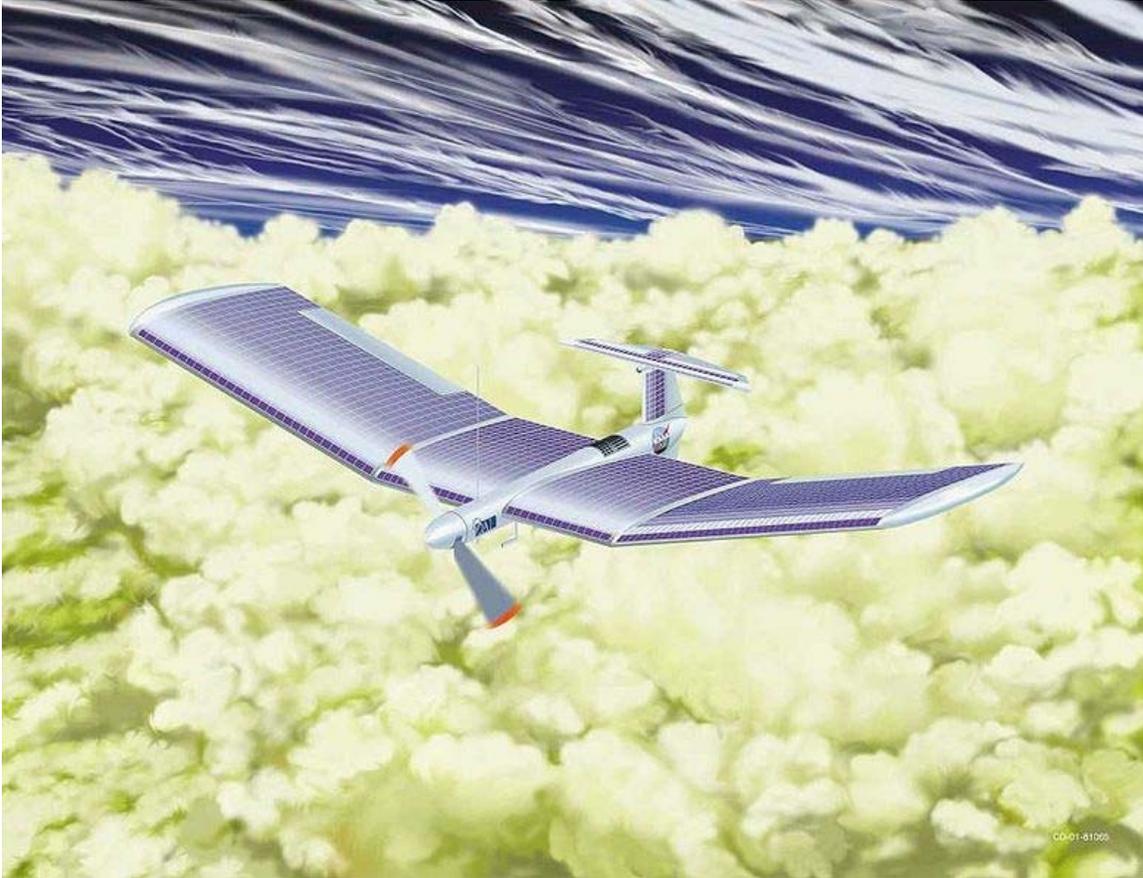
No matter what form the Titan Biologic Explorer mission takes, the system would likely require an atomic-powered radioisotope thermoelectric generator module for power. Solar power would not be possible at Saturn's distance and under Titan's smog, and batteries would not give adequate mission endurance. The aerobot would also carry a miniaturized chemical lab to search for complicated organic chemicals.

Jupiter

Finally, aerobots might be used to explore the atmosphere of Jupiter and possibly the other gaseous outer planets. As the atmospheres of these planets are largely composed of hydrogen, and since there is no lighter gas than hydrogen, such an aerobot would have to be a Montgolfiere. As sunlight is weak at such distances, the aerobot would obtain most of its heating from infrared energy radiated by the planet below.

A Jupiter aerobot might operate at altitudes where the air pressure ranges from one to ten atmospheres, occasionally dropping lower for detailed studies. It would make atmospheric measurements and return imagery and remote sensing of weather phenomena, such as Jupiter's Great Red Spot. A Jupiter aerobot might also drop sondes deep into the atmosphere and relay their data back to an orbiter until the sondes are destroyed by temperature and pressure.

Planetary Aircraft



Artist's conception for a Venus airplane

Winged airplane concepts have been proposed for robotic exploration in the atmosphere of Mars, Venus, and even Jupiter.

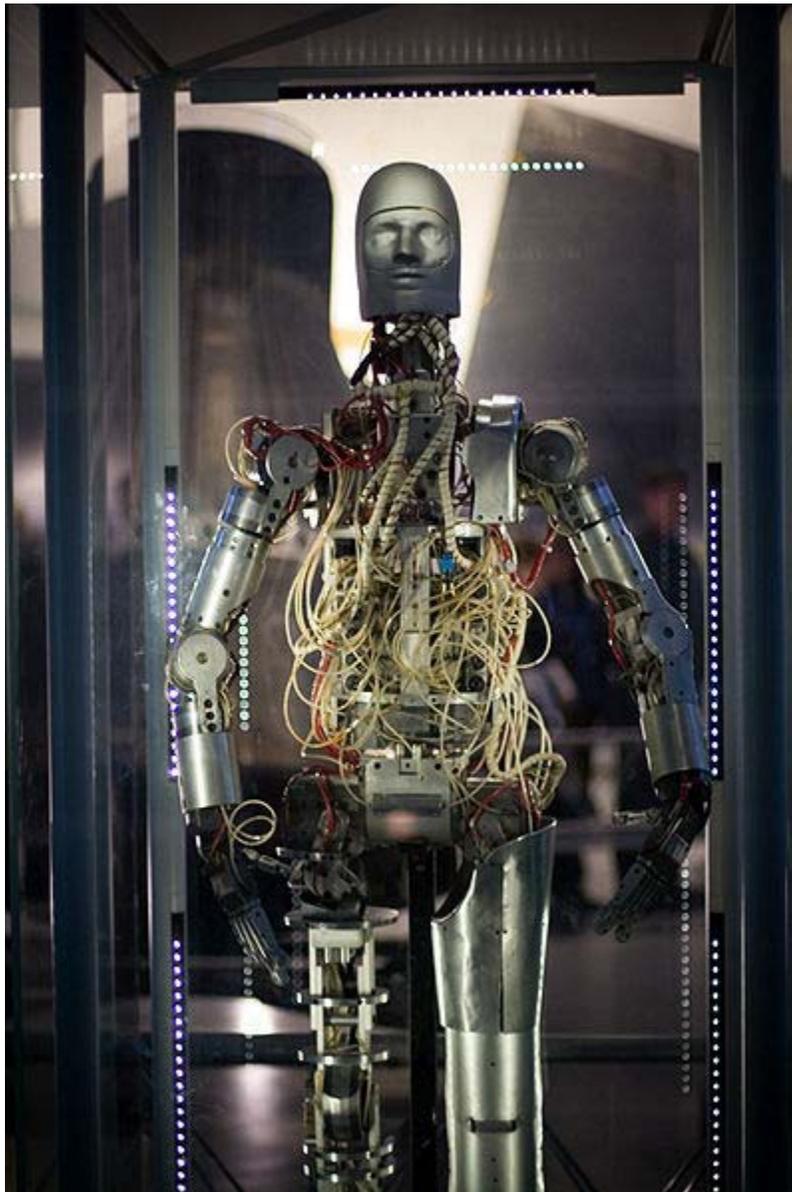
The main technical challenges of flying on Mars include

1. Understanding and modeling the low Reynolds number, high subsonic Mach Number aerodynamics
2. Building appropriate, often unconventional airframe designs and aerostructures
3. Mastering the dynamics of deployment from a descending entry vehicle aeroshell
4. Integrating a non-air breathing propulsion subsystem into the system.

An aircraft concept, ARES was selected for a detailed design study as one of the four finalists for the 2007 Mars Scout Program opportunity, but was eventually not selected in favor of the Phoenix mission. In the design study, both half-scale and full-scale aircraft were tested under Mars-atmospheric conditions.

Chapter- 3

Android (robot)



A fictional android

An **android** is a robot or synthetic organism designed to look and act like a human. "Gynoid" is the feminine form, although "android" is used almost universally to refer to both. Until recently, androids have largely remained within the domain of science fiction, frequently seen in film and television.

Etymology

The word was coined from the Greek root ανδρ- 'man' and the suffix *-oid* 'having the form or likeness of'. The term was first mentioned by St. Albertus Magnus in 1270 and was popularized by the French writer Villiers in his 1886 novel *L'Ève future*. The term "android" appears in US patents as early as 1863 in reference to miniature human-like toy automatons.

The term "droid", coined by George Lucas for the original *Star Wars* film and now used widely within science fiction, originated as an abridgment of "android", but has been used by Lucas and others to mean any robot, including distinctly non-humaniform machines like R2-D2. The abbreviation "andy", coined as a pejorative by writer Philip K. Dick in his novel *Do Androids Dream of Electric Sheep?*, has seen some further usage, such as within the TV series *Total Recall 2070*.

Projects

Japan



DER 01, a Japanese actroid

The Intelligent Robotics Lab, directed by Hiroshi Ishiguro at Osaka University, and Kokoro Co., Ltd. have demonstrated the Actroid at Expo 2005 in Aichi Prefecture, Japan. In 2006, Kokoro Co. developed a new *DER 2* android. The height of the human body part of DER2 is 165 cm. There are 47 mobile points. DER2 can not only change its expression but also move its hands and feet and twist its body. The "air servosystem" which Kokoro Co. developed originally is used for the actuator. As a result of having an actuator controlled precisely with air pressure via a servosystem, the movement is very fluid and there is very little noise. DER2 realized a slimmer body than that of the former version by using a smaller cylinder. Outwardly DER2 has a more beautiful proportion. Compared to the previous model, DER2 has thinner arms and a wider repertoire of expressions. Once programmed, it is able to choreograph its motions and gestures with its voice.

The Intelligent Mechatronics Lab, directed by Hiroshi Kobayashi at the Tokyo University of Science, has developed an android head called *Saya*, which was exhibited at Robodex 2002 in Yokohama, Japan. There are several other initiatives around the world involving humanoid research and development at this time, which will hopefully introduce a broader spectrum of realized technology in the near future. Now *Saya* is *working* at the Science University of Tokyo as a guide.

The Waseda University (Japan) and NTT Docomo's manufacturers have succeeded in creating a shape-shifting robot *WD-2*. It is capable of changing its face. At first, the creators decided the positions of the necessary points to express the outline, eyes, nose, and so on of a certain person. The robot expresses its face by moving all points to the decided positions, they say. The first version of the robot was first developed back in 2003. After that, a year later, they made a couple of major improvements to the design. The robot features an elastic mask made from the average head dummy. It uses a driving system with a 3DOF unit. The *WD-2* robot can change its facial features by activating specific facial points on a mask, with each point possessing three degrees of freedom. This one has 17 facial points, for a total of 56 degrees of freedom. As for the materials they used, the *WD-2*'s mask is fabricated with a highly elastic material called Septom, with bits of steel wool mixed in for added strength. Other technical features reveal a shaft driven behind the mask at the desired facial point, driven by a DC motor with a simple pulley and a slide screw. Apparently, the researchers can also modify the shape of the mask based on actual human faces. To "copy" a face, they need only a 3D scanner to determine the locations of an individual's 17 facial points. After that, they are then driven into position using a laptop and 56 motor control boards. In addition, the researchers also mention that the shifting robot can even display an individual's hair style and skin color if a photo of their face is projected onto the 3D Mask.

Korea



EveR-2, the first android that has the ability to sing

KITECH researched and developed EveR-1, an android interpersonal communications model capable of emulating human emotional expression via facial "musculature" and

capable of rudimentary conversation, having a vocabulary of around 400 words. She is 160 cm tall and weighs 50 kg, matching the average figure of Korean women in their twenties. EveR-1's name derives from the Biblical Eve, plus the letter *r* for *robot*. EveR-1's advanced computing processing power enables speech recognition and vocal synthesis, at the same time processing lip synchronization and visual recognition by 90-degree micro-CCD cameras with face recognition technology. An independent microchip inside her artificial brain handles gesture expression, body coordination, and emotion expression. Her whole body is made of highly advanced synthetic jelly silicon and with 60 artificial joints in her face, neck, and lower body; she is able to demonstrate realistic facial expressions and sing while simultaneously dancing. In South Korea, the Ministry of Information and Communication has an ambitious plan to put a robot in every household by 2020. Several robot cities have been planned for the country: the first will be built in 2009 at a cost of 500 billion won, of which 50 billion is direct government investment. The new robot city will feature research and development centers for manufacturers and part suppliers, as well as exhibition halls and a stadium for robot competitions. The country's new Robotics Ethics Charter will establish ground rules and laws for human interaction with robots in the future, setting standards for robotics users and manufacturers, as well as guidelines on ethical standards to be programmed into robots to prevent human abuse of robots and vice versa.

United States

Hanson Robotics, Inc., of Texas and KAIST produced an android portrait of Albert Einstein, using Hanson's facial android technology mounted on KAIST's life-size walking bipedal robot body. This Einstein android, also called "Albert Hubo", thus represents the first full-body walking android in history. Hanson Robotics, the FedEx Institute of Technology, and the University of Texas at Arlington also developed the android portrait of sci-fi author Philip K. Dick (creator of *Do Androids Dream of Electric Sheep?*, the basis for the film *Blade Runner*), with full conversational capabilities that incorporated thousands of pages of the author's works. In 2005, the PKD android won a first place artificial intelligence award from AAI.

United Kingdom

In 2001, Steve Grand(OBE), creator of the computer game, *Creatures*, created an android, or anthropoid, he named Lucy. The intention was that she would have to learn everything, including how to use her mechanical vocal chords to speak. Her systems were made to be similar to a human's.

Iran

Surena (Persian: انروس) is a humanoid robot which has been developed and fabricated through a joint project between "Center for Advanced Vehicles (CAV), University of Tehran" and "the R&D Society of Iranian Industries and Mines". The project of "Design, Fabrication and Control of the Humanoid Robot (Surena)" was first presented on December 15, 2008 as Surena I. Surena I was an 8 degree-of-freedom (8 DOF) humanoid

robot, which was able to move on a pre-defined trajectory with a tracking and remote control system. Surena project is enhancing the ability to design robots that walk on two legs, under a feedback control system that provides dynamic balance, yielding a much more human-like motion. The work is addressing both theoretical and experimental aspects of bipedal locomotion. On July 3, 2010 the second generation of Surena was unveiled. Surena II has 22 DOFs including 12, 8, and 2 at its legs, hands and head respectively. Its height is 145 cm with a weight of 45 kg. Surena is a product of more than 10,000 hours of hard work by a team of 20 engineers and students. Surena II is equipped with various sensors such as gyroscope and accelerometers which provide stable motion. A Multi-Input Multi-Output (MIMO) control system is employed to provide a smooth walk. Surena II is a humanoid robot that balances itself and walks freely. The robot has the shape and size of a standard human, making it the first anthropomorphic robot in Iran that moves dynamically like a real human. The anthropomorphic nature of Surena makes it a wonderful robot for motivating very challenging problems in engineering, without having to assume familiarity with advanced mathematics or physics. In this context, the concepts of dynamics, stability, sensing, actuation and feedback control become interesting and understandable to a broad audience. The intrinsic attraction of Surena has been employed as a forum to demonstrate to students and to the public the excitement of a career in engineering. A major benefit of our approach is that we evaluate the capability of the theory to tolerate model imperfections. This is accomplished through experiments on Surena . The successful operation of Surena requires equally innovative feedback control theory that works in concert with the natural dynamics of the system to achieve stability and robustness of the implemented behaviors.

Surena III is in fact the follow-up of the 2nd phase and is developed with the aim of upgrading and AI programming of Surena II. The features of robot in this phase are new movement/behavior scenarios, word/statement identification and vision. ”

Speech and vision development are on the way in the next generation of Surena . Presently, Surena team is working on the development of a more advanced version of Surena with a faster maneuverability and higher level of machine intelligence suitable for various industrial, medical and household applications.

Surena II

Surena II (Persian: انروس) is a humanoid robot which has been developed and fabricated through a joint project between “Center for Advanced Vehicles (CAV), University of Tehran” and “the R&D Society of Iranian Industries and Mines”. The project of “Design, Fabrication and Control of the Humanoid Robot (Surena)” was first presented on December 15, 2008 as Surena I. Surena I was an 8 degree-of-freedom (8 DOF) humanoid robot, which was able to move on a pre-defined trajectory with a tracking and remote control system. Surena project is enhancing the ability to design robots that walk on two legs, under a feedback control system that provides dynamic balance, yielding a much

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Speech and vision development are on the way in the next generation of Surena . Presently, Surena team is working on the development of a more advanced version of Surena with a faster maneuverability and higher level of machine intelligence suitable for various industrial, medical and household applications.(SURENA III)

Usage and distinctions

Unlike the terms "robot" (a "mechanical" being) and *cyborg* (a being that is partly organic and partly mechanical), the word "android" has been used in literature and other media to denote several different kinds of artificially constructed beings:

- a robot that closely resembles a human
- an artificially or synthetically created being that closely resembles a human; also referred to in many series (mostly anime) as Bio Android
- any machine that mimics a human

Although human morphology is not necessarily the ideal form for working robots, the fascination in developing robots that can mimic it can be found historically in the assimilation of two concepts: *simulacra* (devices that exhibit likeness) and *automata* (devices that have independence).

The term *android* was popularized by the French author Auguste Villiers de l'Isle-Adam in his work *Tomorrow's Eve* (1886), featuring an artificial humanlike robot named

Hadaly. As said by the officer in the story, "In this age of Realien advancement, who knows what goes on in the mind of those responsible for these mechanical dolls."

Although Karel Čapek's robots in *R.U.R. (Rossum's Universal Robots)* (1921) – the play that introduced the word *robot* to the world – were organic artificial humans, the word "robot" has come to primarily refer to mechanical humans, animals, and other beings. The term "android" can mean either one of these, while a cyborg ("cybernetic organism" or "bionic man") would be a creature that is a combination of organic and mechanical parts.

The word "android" is a combination of Ancient Greek *andros* and the suffix *-oid*, which literally means "in the form of a man (male human being)". This could be contrasted with the more general term "anthropoid", which means humanlike. According to this fashion, a female human-like robot would be a "gynoid".

Fiction



Data from *Star Trek*, a fictional android

Androids are a staple of science fiction. Authors have used the term *android* in more diverse ways than *robot* or *cyborg*. In some fictional works, the difference between a robot and android is only their appearance, with androids being made to look like humans on the outside but with robot-like internal mechanics. In other stories, authors have used

the word "android" to mean a wholly organic, yet artificial, creation. Other fictional depictions of androids fall somewhere in between.

One thing common to most fictional androids, though, is that the real-life technological challenges associated with creating thoroughly human-like robots – such as the creation of strong artificial intelligence – are assumed to have been solved. Fictional androids are generally depicted as mentally and physically equal or superior to humans – moving, thinking and speaking as fluidly as them.

The tension between the nonhuman substance and the human appearance – or even human ambitions – of androids is the dramatic impetus behind most of their fictional depictions. Some android heroes seek, like Pinocchio, to become human, as in the films *Bicentennial Man*, *Hollywood*, *Enthiran* and *A.I. Artificial Intelligence*, or Data in the science-fiction show *Star Trek: The Next Generation*. Others, as in the film *Westworld*, rebel against abuse by careless humans. Android hunter Deckard in American writer Philip K. Dick's *Do Androids Dream of Electric Sheep?* discovers that his targets are, in some ways, more human than he is. Android stories, therefore, are not essentially stories "about" androids; they are stories about the human condition and what it means to be human.

One aspect of writing about the meaning of humanity is to use discrimination against androids as a mechanism for exploring racism in society, as in *Do Androids Dream of Electric Sheep?* and its film adaptation *Blade Runner*. Perhaps the clearest example of such an exploration is John Brunner's 1968 novel *Into the Slave Nebula*, where the blue-skinned android slaves are explicitly shown to be fully human. More recently, the androids Lance Bishop and Annalee Call in the films *Aliens* and *Alien Resurrection* are used as vehicles for exploring how humans deal with the presence of an "Other".

Female androids, or "gynoids", are often seen in science fiction, and can be viewed as a continuation of the long tradition of men attempting to create the stereotypical "perfect woman". Examples include the Greek myth of *Pygmalion*, the fembots in the Austin Powers series, and the female robot Maria in Fritz Lang's *Metropolis*. Some gynoids, like Pris in *Blade Runner*, are designed as sex-objects, with the intent of "pleasing men's violent sexual desires". Fiction about gynoids or female cyborgs has therefore been described as reinforcing "essentialist ideas of femininity", although others have suggested that the treatment of androids is a way of exploring racism and misogyny in society.

Chapter- 4

Powered Exoskeleton



A **powered exoskeleton** is a powered mobile machine consisting primarily of an exoskeleton-like framework worn by a person and a power supply that supplies at least part of the activation-energy for limb movement.

Powered exoskeletons are designed to assist and protect the wearer. They may be designed, for example, to assist and protect soldiers and construction workers, or to aid the survival of people in other dangerous environments. A wide medical market exists in the future of prosthetics to provide mobility assistance for aged and infirm people. Other possibilities include rescue work, such as in collapsed buildings, in which the device might allow a rescue worker to lift heavy debris, while simultaneously protecting the worker from falling rubble.

Working examples of powered exoskeletons have been constructed but are not currently widely deployed. Various problems remain to be solved, including suitable power-supply. However three companies launched exoskeleton suits for people with disabilities in 2010.

A fictional mecha is different from a powered exoskeleton in that the mecha is typically much larger than a normal human body, and does not directly enhance the motion or strength of the physical limbs. Instead the human operator occupies a cabin or pilot's control seat inside a small portion of the larger system. Within this cabin the human may wear a small lightweight exoskeleton that serves as a haptic control interface for the much larger exterior appendages.

History

The first exoskeleton was co-developed by General Electric and the United States military in the 1960s, named Hardiman, which made lifting 250 pounds (110 kg) feel like lifting 10 pounds (4.5 kg). It was impractical due to its 1,500 pounds (680 kg) weight. The project was not successful. Any attempt to use the full exoskeleton resulted in a violent uncontrolled motion, and as a result it was never tested with a human inside. Further research concentrated on one arm. Although it could lift its specified load of 750 pounds (340kg), it weighed three quarters of a ton, just over twice the liftable load. Without getting all the components to work together the practical uses for the Hardiman project were limited.

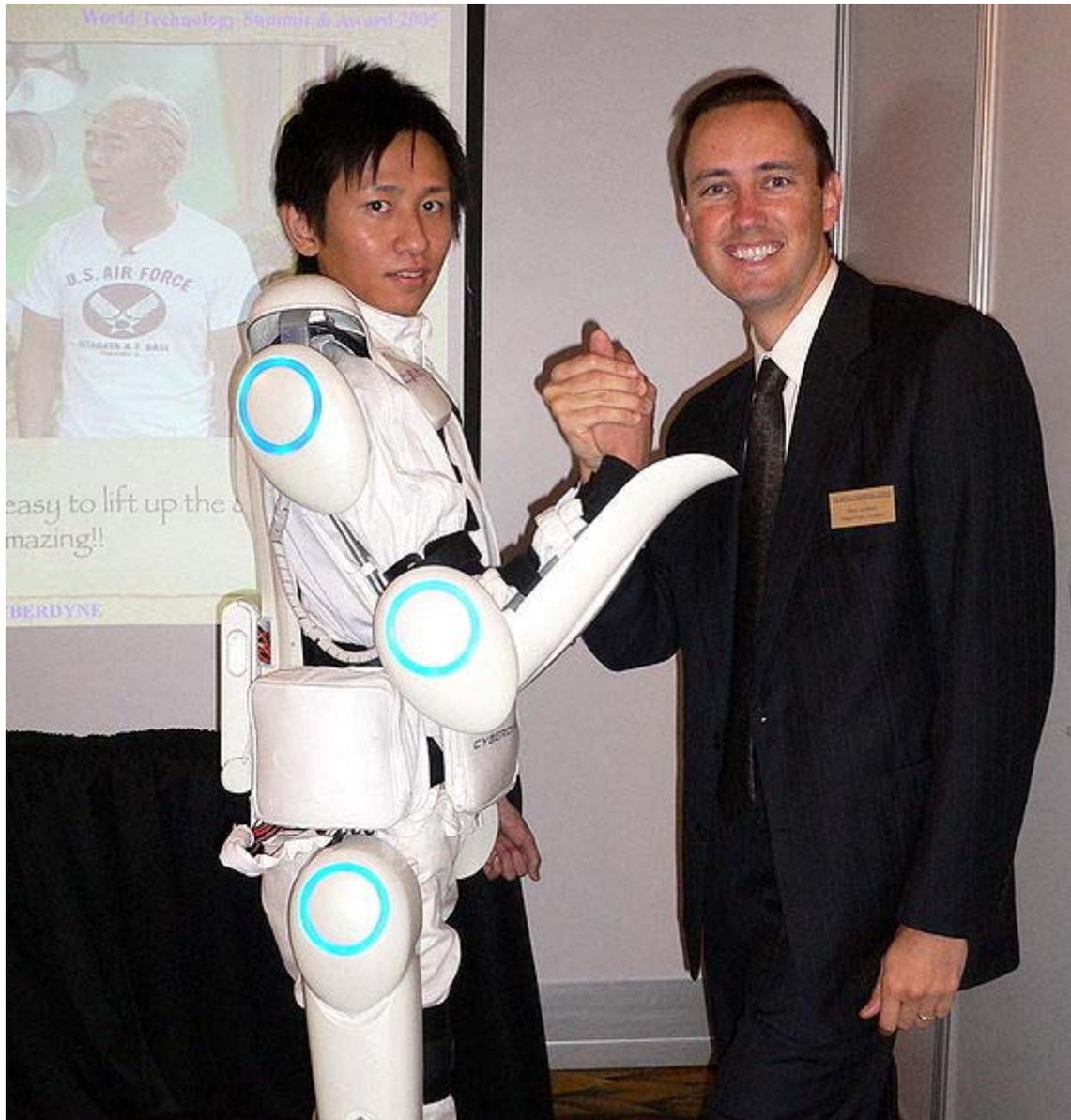
Fictional powered exoskeletons

Many variations of exoskeletons can be found in science fiction and gaming (e.g. Warhammer 40,000). It was first popularized in Robert A. Heinlein's 1959 novel *Starship Troopers* where powered armor was used by the Mobile Infantry. Powered armor also is a central feature in the science fiction novels *The Forever War* by Joe Haldeman and *Armor* by John Steakley.

While a realistic visual depiction of powered armor had long been a challenge for practical (live actor in a suit) filming, advances in computer animation have opened the door for several powered armor-centric movies including the film *Iron Man*, its sequel, and *G.I. Joe: The Rise of Cobra*. Science fiction video games such as *Metroid*, *Crysis*, *Fallout*, *Starcraft* and *Warhammer 40,000* focus on elaborate representations of powered armor. Several cartoons and Japanese animation have also depicted similar concepts for powered exoskeletons such as ground troops in *Exosquad* (American series) and *Appleseed* (Japanese series).

While these technologies are clearly over the horizon in terms of current machine and material science, DARPA is actively pursuing a multi-million dollar program "Concepts of Operations for Exoskeletons for Human Performance Augmentation (EHPA)" to develop them.

Applications



A Hybrid Assistive Limb powered exoskeleton suit, currently in development.

One of the proposed main uses for an exoskeleton would be enabling a soldier to carry heavy objects (80–300 kg) while running or climbing stairs. Not only could a soldier potentially carry more weight, he could presumably wield heavier armor and weapons. Most models use a hydraulic system controlled by an on-board computer. They could be powered by an internal combustion engine, batteries or, potentially, fuel cells. Another area of application could be medical care, nursing in particular. Faced with the impending shortage of medical professionals and the increasing number of people in elderly care, several teams of Japanese engineers have developed exoskeletons designed to help nurses lift and carry patients.

Exoskeletons could also be applied in the area of rehabilitation of stroke or SCI patients. Such exoskeletons are sometimes also called Step Rehabilitation Robots. An exoskeleton could reduce the number of therapists needed by allowing even the most impaired patient to be trained by one therapist, whereas several are currently needed. Also training could be more uniform, easier to analyze retrospectively and can be specifically customized for each patient. At this time there are several projects designing training aids for rehabilitations centers (LOPES exoskeleton, LOKOMAT, ALTACRO and the gait trainer, Hal 5.)

Exoskeletons could also be regarded as wearable robots: A wearable robot is a mechatronic system that is designed around the shape and function of the human body, with segments and joints corresponding to those of the person it is externally coupled with. Teleoperation and power amplification were said to be the first applications, but after recent technological advances the range of application fields is said to have widened. Increasing recognition from the scientific community means that this technology is now employed in telemanipulation, man-amplification, neuromotor control research and rehabilitation, and to assist with impaired human motor control (*Wearable Robots: Biomechatronic Exoskeletons*).

Current Research

Los Alamos Laboratories worked on an exoskeleton project in the 1960s called Project Pitman. In 1986, an exoskeleton prototype called the LIFESUIT was created by Monty Reed, a US Army Ranger who had broken his back in a parachute accident. While recovering in the hospital, he read Robert Heinlein's *Starship Troopers* and from Heinlein's description of Mobile Infantry Power Suits, he designed the LIFESUIT, and wrote letters to the military about his plans for the LIFESUIT. In 2001 LIFESUIT One (LSI) was built. In 2003 LS6 was able to record and play back a human gait. In 2005 LS12 was worn in a foot race known as the Saint Patrick's' Day Dash in Seattle, Washington. Monty Reed and LIFESUIT XII set the Land Speed Distance Record for walking in robot suits. LS12 completed the 3-mile race in 90 minutes. The current LIFESUIT prototype 14 can walk one mile on a full charge and lift 92 kg (203 lbs) for the wearer.

In January 2007, *Newsweek* magazine reported that the Pentagon had granted development funds to The University of Texas at Dallas' nanotechnologist Ray Baughman to develop military-grade artificial myomer fibers. These electrically-contractive fibers are intended to increase the strength-to-weight ratio of movement systems in military powered armor.

Current exoskeletons

- UC Berkeley/Lockheed Martin HULC legs, the primary competitor to Sarcos/Raytheon. Allows the user to carry up to 200 lbs (90kg) on a backpack attached to the exoskeleton independent of the user.

- Cyberdyne's HAL 5 arms/legs. Allows the wearer to lift 10 times as much as they normally could.
- Honda Exoskeleton Legs. Weighs 14.3 lbs (6.5kg) and features a seat for the wearer.
- M.I.T. Media Lab's Biomechatronics Group legs. Weighs 11.7 kg (26 lbs).
- Sarcos/Raytheon XOS Exoskeleton arms/legs. For use in the military and to "replace the wheelchair", weighs 150 lbs (68kg) and allows the wearer to lift 200 lbs (90kg) with little or no effort. Recently, the XOS 2 was unveiled, which featured more fluid movement, increase in power output and decrease in power input.
- Rex Bionics' Rex, Robotic Exoskeleton Legs. Weighs 84 lbs (38kg). Enables wheelchair users to stand up, walk, move sideways, turn around, go up and down steps as well as walk on flat hard surfaces including ramps and slopes.

Limitations and design issues

Engineers of powered exoskeletons face a number of large technological challenges to build a suit that is capable of quick and agile movements, yet is also safe to operate without extensive training.

Power supply

One of the largest problems facing designers of powered exoskeletons is the power supply. There are currently few power sources of sufficient energy density to sustain a full-body powered exoskeleton for more than a few minutes. Most research designs are tethered to a much larger separate power source.

For a powered exoskeleton that will not need to be used in completely standalone situations such as a battlefield soldier, this limitation may be acceptable, and the suit may be designed to be used with a permanent power umbilical.

Strong but lightweight skeleton

Initial exoskeleton experiments are commonly done using inexpensive and easy to mold materials such as steel and aluminum. However steel is heavy and the powered exoskeleton must work harder to overcome its own weight in order to assist the wearer, reducing efficiency. Aluminum is lightweight but also not very strong; it would be unacceptable for the exoskeleton to fail catastrophically in a high-load condition by "folding up" on itself and injuring the wearer.

As the design moves past the initial exploratory steps, the engineers move to progressively more expensive and strong but lightweight materials such as titanium, and use more complex component construction methods, such as as molded carbon-fiber plates.

Strong but lightweight actuators

The powerful but lightweight design issues are also true of the joint actuators. Standard hydraulic cylinders are powerful and capable of being precise, but they are also heavy due to the fluid-filled hoses and actuator cylinders, and the fluid has the potential to leak onto the user. Pneumatics are generally too unpredictable for precise movement since the compressed gas is springy, and the length of travel will vary with the gas compression and the reactive forces pushing against the actuator.

Generally electronic servomotors are more efficient and power-dense, utilizing high-gauss permanent magnets and step-down gearing to provide high torque and responsive movement in a small package. Geared servomotors can also utilize electronic braking to hold in a steady position while consuming minimal power.

Joint flexibility

Flexibility is another design issue. Several human joints such as the hips and shoulders are ball and socket joints, with the center of rotation inside the body. It is difficult for an exoskeleton to exactly match the motions of this ball joint using a series of external single-axis hinge points, limiting flexibility of the wearer.

A separate exterior ball joint can be used alongside the shoulder or hip, but this then forms a series of parallel rods in combination with the wearer's bones. As the external ball joint is rotated through its range of motion, the positional length of the knee/elbow joint will lengthen and shorten, causing joint misalignment with the wearer's body. This slop in suit alignment with the wearer can be permitted, or the suit limbs can be designed to lengthen and shorten under power assist as the wearer moves, to keep the knee/elbow joints in alignment.

A partial solution for more accurate free-axis movement is a hollow spherical ball joint that encloses the human joint, with the human joint as the center of rotation for the hollow sphere. Rotation around this joint may still be limited unless the spherical joint is composed of several plates that can either fan out or stack up onto themselves as the human ball joint moves through its full range of motion.

Spinal flexibility is another challenge since the spine is effectively a stack of limited-motion ball joints. There is no simple combination of external single-axis hinges that can easily match the full range of motion of the human spine. A chain of external ball joints behind the spine can perform a close approximation, though it is again the parallel-bar length problem. Leaning forward from the waist, the suit shoulder joints would press down into the wearer's body. Leaning back from the waist, the suit shoulder joints would lift up off the wearer's body. Again, this alignment slop with the wearer's body can be permitted, or the suit can be designed to rapidly lengthen or shorten the exoskeleton spine under power assist as the wearer moves.

Power control and modulation

Control and modulation of excessive and unwanted movement is a third large problem. It is not enough to build a simple single-speed assist motor, with forward/hold/reverse position controls and no on-board computer control. Such a mechanism can be too fast for the user's desired motion, with the assisted motion overshooting the desired position.

If the wearer's body is enclosed with simple contact surfaces that trigger suit motion, the overshoot can result the wearer's body lagging behind the suit limb position, resulting in contact with a position sensor to move the exoskeleton in the opposite direction. This lagging of the wearer's body can lead to an uncontrolled high-speed oscillatory motion, and a powerful assist mechanism can batter or injure the operator unless shut down remotely.

A single-speed assist mechanism which is slowed down to prevent oscillation is then restrictive on the agility of the wearer. Sudden unexpected movements such as tripping or being pushed over requires fast precise movements to recover and prevent falling over, but a slow assist mechanism may simply collapse and injure the user inside.

Fast and accurate assistive positioning is typically done using a range of speeds controlled using computer position sensing of both the exoskeleton and the wearer, so that the assistive motion only moves as fast or as far as the motion of the wearer and does not overshoot or undershoot. This may involve rapidly accelerating and decelerating the motion of the suit to match the wearer, so that their limbs slightly press against the interior of the suit and then it moves out of the way to match the wearer's motion. The computer control also needs to be able to detect unwanted oscillatory motions and shut down in a safe manner if damage to the overall system occurs.

Detection of unsafe/invalid motions

A fourth issue is detection and prevention of invalid or unsafe motions. It would be unacceptable for an exoskeleton to be able to move in a manner that exceeds the range of motion of the human body and tear muscle ligaments. This problem can be partially solved using designed limits on hinge motion, such as not allowing the knee or elbow joints to flex backwards onto themselves.

However, the wearer of a powered exoskeleton can additionally damage themselves or the suit by moving the hinge joints through a series of combined and otherwise valid movements which together cause the suit to collide with itself or the wearer.

A powered exoskeleton would need to be able to computationally track limb positions and limit movement so that the wearer does not casually injure themselves through unintended assistive motions, such as when coughing, sneezing, when startled, or if experiencing a sudden uncontrolled seizure or muscle spasm.

Pinching and joint fouling

An exoskeleton is typically constructed of very strong and hard materials, while the human body is soft and jelly-like. An exoskeleton typically cannot be worn directly in contact with bare skin due to the potential for skin pinching where the exoskeleton plates and servos slide across each other. Instead the wearer may be enclosed in a heavy fabric suit to protect them from joint pinch hazards.

The exoskeleton joints themselves are also prone to environmental fouling from sand and grit, and may need protection from the elements to keep operating effectively. A traditional way of handling this is with seals and gaskets around rotating parts, but can also be accomplished by enclosing the exoskeleton mechanics in a tough fabric suit separate from the user, which functions as a protective "skin" for the exoskeleton. This enclosing suit around the exoskeleton can also protect the wearer from pinch hazards.

Chapter- 5

Automated Guided Vehicle

An **automated guided vehicle** or **automatic guided vehicle** (AGV) is a mobile robot that follows markers or wires in the floor, or uses vision or lasers. They are most often used in industrial applications to move materials around a manufacturing facility or a warehouse. Application of the automatic guided vehicle has broadened during the late 20th century and they are no longer restricted to industrial environments.



Heavy-duty AGV



Tow Type AGV



Light-duty assembly AGV



Inertial-guided automatic trailer loading vehicle



Laser Guided Unitload AGV

Introduction

Automated guided vehicles (AGVs) increase efficiency and reduce costs by helping to automate a manufacturing facility or warehouse. The AGV can tow objects behind them in trailers to which they can autonomously attach. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. The objects can be placed on a set of motorized rollers (conveyor) and then pushed off by reversing them. Some AGVs use fork lifts to lift objects for storage. AGVs are employed in nearly every industry, including, pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done.

An AGV can also be called a laser guided vehicle (LGV) or self-guided vehicle (SGV). In Germany the technology is also called *Fahrerlose Transportsysteme* (FTS) and in Sweden *förlösa truckar*. Lower cost versions of AGVs are often called Automated Guided Carts (AGCs) and are usually guided by magnetic tape. AGCs are available in a variety of models and can be used to move products on an assembly line, transport goods throughout a plant or warehouse, and deliver loads to and from stretch wrappers and roller conveyors.

The first AGV was brought to market in the 1950s, by Barrett Electronics of Northbrook, Illinois, and at the time it was simply a tow truck that followed a wire in the floor instead of a rail. Over the years the technology has become more sophisticated and today automated vehicles are mainly Laser navigated e.g. LGV (Laser Guided Vehicle). In an automated process, LGVs are programmed to communicate (via an offboard server) with other robots to ensure product is moved smoothly through the warehouse, whether it is being stored for future use or sent directly to shipping areas. Today, the AGV plays an important role in the design of new factories and warehouses, safely moving goods to their rightful destinations.

In the late 20th century AGVs took on new roles as ports began turning to this technology to move ISO shipping containers. The Port of Rotterdam employs well over 100 AGVs.

AGV applications are seemingly endless as capacities can range from just a few pounds to hundreds of tons.

Flexible manufacturing system

To begin to understand AGV it is necessary to understand the fundamentals of flexible manufacturing systems (FMS). FMS is a means by which to manufacture a product. FMS is more of a philosophy rather than a tangible item. FMS is the idea that faster is better and uses machines to produce their products. Rather than using humans to perform repetitive tasks a machine is used to perform that task 24 hours a day. FMS uses computer numerical controlled machines (CNC) to form a work cell. Each cell performs a specific task to assist in the manufacturing of a product. Although FMS is fast and efficient it is not cheap as it requires a lot of expensive machines in order to work. Typically, it costs millions of dollars to introduce an FMS into a factory. Rather than using a complete FMS, most companies use part of an FMS called a flexible manufacturing cell. This is used to produce part of a product by machine and maybe part by other methods. Often one or more AGV's are used in FMS to connect work cells together.



Laser-guided AGV to transport unit loads or skids.

Navigation

Wired

The wired sensor is placed on the bottom of the robot and is placed facing the ground. A slot is cut in the ground and a wire is placed approximately 1 inch below the ground. The sensor detects the radio frequency being transmitted from the wire and follows it.

Guide Tape

Many light duty AGVs (some known as automated guided carts or AGCs) use tape for the guide path. The tapes can be one of two styles: magnetic or colored. The AGC is fitted with the appropriate guide sensor to follow the path of the tape. One major advantage of tape over wired guidance is that it can be easily removed and relocated if the course needs to change. It also does not involve the expense of cutting the factory or warehouse floor for the entire travel route. Additionally, it is considered a "passive" system since it does not require the guide medium to be energized as wire does. Colored tape is initially less expensive, but lacks the advantage of being embedded in high traffic areas where the tape may become damaged or dirty. A flexible magnetic bar can also be embedded in the floor like wire but works under the same provision as magnetic tape and so remains unpowered or passive.

Laser Target Navigation

The wireless navigation is done by mounting retroreflective tape on walls, poles or machines. The AGV carries a laser transmitter and receiver on a rotating turret. The laser is sent off then received again the angle and (sometimes) distance are automatically calculated and stored into the AGV's memory. The AGV has reflector map stored in memory and can correct its position based on errors between the expected and received measurements. It can then navigate to a destination target using the constantly updating position.

- **Modulated Lasers** The use of modulated laser light gives greater range and accuracy over pulsed laser systems. By emitting a continuous fan of modulated laser light a system can obtain an uninterrupted reflection as soon as the scanner achieves line of sight with a reflector. The reflection ceases at the trailing edge of the reflector which ensures an accurate and consistent measurement from every reflector on every scan. The LS9 Scanner is manufactured by Guidance Navigation Ltd and, by using a modulated laser; this system achieves an angular resolution of ~ 0.1 mrad (0.006°) at 8 scanner revolutions per second.
- **Pulsed Lasers** A typical pulsed laser scanner emits pulsed laser light at a rate of 14,400 Hz which gives a maximum possible resolution of ~ 3.5 mrad (0.2°) at 8 scanner revolutions per second. To achieve a workable navigation, the readings must be interpolated based on the intensity of the reflected laser light, to identify the centre of the reflector.

Gyroscopic Navigation

Another form of an AGV guidance is inertial navigation. With inertial guidance, a computer control system directs and assigns tasks to the vehicles. Transponders are embedded in the floor of the work place. The AGV uses these transponders to verify that the vehicle is on course. A gyroscope is able to detect the slightest change in the direction of the vehicle and corrects it in order to keep the AGV on its path. The margin of error for the inertial method is ± 1 inch.

Inertial can operate in nearly any environment including tight aisles or extreme temperatures.



Unit-load AGV using natural-features navigation to carry steel to quality assurance lab

Natural Features Navigation

Navigation without retrofitting of the workspace is called Natural Features Navigation. One method uses one or more range-finding sensors, such as a laser range-finder, as well as gyroscopes and/or inertial measurement units with Monte-Carlo/Markov localization techniques to understand where it is as it dynamically plans the shortest permitted path to its goal. The advantage of such systems is that they are highly flexible for on-demand delivery to any location. They can handle failure without bringing down the entire manufacturing operation, since AGVs can plan paths around the failed device. They also are quick to install, with less down-time for the factory.

Steering control

To help an AGV navigate it can use two different steer control systems. The differential speed control is the most common. In this method there are two sets of wheels being driven. Each set is connected to a common drive train. These drive trains are driven at different speeds in order to turn or the same speed to allow the AGV to go forwards and/or backwards. The AGV turns in a similar fashion to a tank. This method of steering is good in the sense that it is easy to maneuver in small spaces. More often than not, this is seen on an AGV that is used to transport and turn in tight spaces or when the AGV is working near machines. This setup for the wheels is not used in towing applications because the AGV would cause the trailer to jackknife when it turned.

The other type of steering used is steered wheel control AGV. This type of steering is similar to a cars steering. It is more precise in following the wire program than the differential speed controlled method. This type of AGV has smoother turning but cannot

make sharp turns in tight spots. Steered wheel control AGV can be used in all applications; unlike the differential controlled. Steered wheel control is used for towing and can also at times have an operator control it.

Path Decision

AGVs have to make decisions on path selection. This is done through different methods: frequency select mode (wired navigation only), and path select mode (wireless navigation only) or via a magnetic tape on the floor not only to guide the AGV but also to issue steering commands and speed commands.

Frequency select mode

Frequency select mode bases its decision on the frequencies being emitted from the floor. When an AGV approaches a point on the wire which splits the AGV detects the two frequencies and through a table stored in its memory decides on the best path. The different frequencies are required only at the decision point for the AGV. The frequencies can change back to one set signal after this point. This method is not easily expandable and requires extra guide cutting meaning more money.

Path select mode

An AGV using the path select mode chooses a path based on preprogrammed paths. It uses the measurements taken from the sensors and compares them to values given to them by programmers. When an AGV approaches a decision point it only has to decide whether to follow path 1, 2, 3, etc. This decision is rather simple since it already knows its path from its programming. This method can increase the cost of an AGV because it is required to have a team of programmers to program the AGV with the correct paths and change the paths when necessary. This method is easy to change and set up.

Magnetic Tape mode

The magnetic tape is laid on the surface of the floor or buried in a 10 mm channel, not only does it provide the path for the AGV to follow but also sort strips of the tape in different combos of the strip tell the AGV to change lane and also speed up slow down and stop with north and south magnetic combos, this is used by TOYOTA USA and TOYOTA JAPAN.

Traffic Control

Flexible manufacturing systems containing more than one AGV may require it to have traffic control so the AGV's will not run into one another. Methods include zone control, forward sensing control, and combination control each method has its advantages and disadvantages.

Zone control

Zone control is the favorite of most environments because it is simple to install and easy to expand. Zone control uses a wireless transmitter to transmit a signal in a fixed area. Each AGV contains a sensing device to receive this signal and transmit back to the transmitter. If the area is clear the signal is set at “clear” allowing any AGV to enter and pass through the area. When an AGV is in the area the “stop” signal is sent and all AGV attempting to enter the area stop and wait for their turn. Once the AGV in the zone has moved out beyond the zone the “clear” signal is sent to one of the waiting AGVs. Another way to set up zone control traffic management is to equip each individual robot with its own small transmitter/receiver. The individual AGV then sends its own “do not enter” message to all the AGVs getting to close to its zone in the area. A problem with this method is if one zone goes down all the AGV’s are at risk to collide with any other AGV. Zone control is a cost efficient way to control the AGV in an area.

Forward sensing control

Forward sensing control uses collision avoidance sensors to avoid collisions with other AGV in the area. These sensors include: sonic, which work like radar; optical, which uses an infrared sensor; and bumper, physical contact sensor. Most AGVs are equipped with a bumper sensor of some sort as a fail safe. Sonic sensors send a “chirp” or high frequency signal out and then wait for a reply from the outline of the reply the AGV can determine if an object is ahead of it and take the necessary actions to avoid collision. The optical uses an infrared transmitter/receiver and sends an infrared signal which then gets reflected back; working on a similar concept as the sonic sensor. The problems with these are they can only protect the AGV from so many sides. They are relatively hard to install and work with as well.

Combination control

Combination control sensing is using collision avoidance sensors as well as the zone control sensors. The combination of the two helps to prevent collisions in any situation. For normal operation the zone control is used with the collision avoidance as a fail safe. For example, if the zone control system is down, the collision avoidance system would prevent the AGV from colliding.

System Management

Industries with AGVs need to have some sort of control over the AGVs. There are three main ways to control the AGV: locator panel, CRT color graphics display, and central logging and report.

A locator panel is a simple panel used to see which area the AGV is in. If the AGV is in one area for too long, it could mean it is stuck or broken down. CRT color graphics display shows real time where each vehicle is. It also gives a status of the AGV, its

battery voltage, unique identifier, and can show blocked spots. Central logging used to keep track of the history of all the AGVs in the system. Central logging stores all the data and history from these vehicles which can be printed out for technical support or logged to check for up time.

AGV is a system often used in FMS to keep up, transport, and connect smaller subsystems into one large production unit. AGVs employ a lot of technology to ensure they do not hit one another and make sure they get to their destination. Loading and transportation of materials from one area to another is the main task of the AGV. AGV require a lot of money to get started with, but they do their jobs with high efficiency. In places such as Japan automation has increased and is now considered to be twice as efficient as factories in America. For a huge initial cost the total cost over time decreases

Vehicle Types

- *AGVS Towing Vehicles* were the first type introduced and are still a very popular type today. Towing vehicles can pull a multitude of trailer types and have capacities ranging from 8,000 pounds to 60,000 pounds.
- *AGVS Unit Load Vehicles* are equipped with decks, which permit unit load transportation and often automatic load transfer. The decks can either be lift and lower type, powered or non-powered roller, chain or belt decks or custom decks with multiple compartments.
- *AGVS Pallet Trucks* are designed to transport palletized loads to and from floor level; eliminating the need for fixed load stands.
- *AGVS Fork Truck* has the ability to service loads both at floor level and on stands. In some cases these vehicles can also stack loads in rack.
- *Light Load AGVS* are vehicles which have capacities in the neighborhood of 500 pounds or less and are used to transport small parts, baskets, or other light loads though a light manufacturing environment. They are designed to operate in areas with limited space.
- *AGVS Assembly Line Vehicles* are an adaptation of the light load AGVS for applications involving serial assembly processes.

Common AGV Applications

Automated Guided Vehicles can be used in a wide variety of applications to transport many different types of material including pallets, rolls, racks, carts, and containers. AGVs excel in applications with the following characteristics:

- Repetitive movement of materials over a distance
- Regular delivery of stable loads

- Medium throughput/volume
- When on-time delivery is critical and late deliveries are causing inefficiency
- Operations with at least two shifts
- Processes where tracking material is important

Raw Material Handling

AGVs are commonly used to transport raw materials such as paper, steel, rubber, metal, and plastic. This includes transporting materials from receiving to the warehouse, and delivering materials directly to production lines.

Work-in-Process Movement

Work-in-Process movement is one of the first applications where automated guided vehicles were used, and includes the repetitive movement of materials throughout the manufacturing process. AGVs can be used to move material from the warehouse to production/processing lines or from one process to another.

Pallet Handling

Pallet handling is an extremely popular application for AGVs as repetitive movement of pallets is very common in manufacturing and distribution facilities. AGVs can move pallets from the palletizer to stretch wrapping to the warehouse/storage and/or to the outbound shipping docks.

Finished Product Handling

Moving finished goods from manufacturing to storage or shipping is the final movement of materials before they are delivered to customers. These movements often require the gentlest material handling because the products are complete and subject to damage from rough handling. Because AGVs operate with precisely controlled navigation and acceleration and deceleration this minimizes the potential for damage making them an excellent choice for this type of application.

Trailer Loading

Automatic loading of trailers is a relatively new application for automated guided vehicles and becoming increasingly popular. AGVs are used to transport and load pallets of finished goods directly into standard, over-the-road trailers without any special dock equipment. AGVs can pick up pallets from conveyors, racking, or staging lanes and deliver them into the trailer in the specified loading pattern.

Roll Handling

AGVs are used to transport rolls in many types of plants including paper mills, converters, printers, newspapers, steel producers, and plastics manufacturers. AGVs can

store and stack rolls on the floor, in racking, and can even automatically load printing presses with rolls of paper.

Primary Application Industries

Efficient, cost effective movement of materials is an important, and common element in improving operations in many manufacturing plants and warehouses. Because automatic guided vehicles (AGVs) can delivery efficient, cost effective movement of materials, AGVs can be applied to various industries in standard or customized designs to best suit an industry's requirements. Industry's currently utilizing AGVs include (but are not limited to):



A forktruck vehicle delivering a pallet of finished goods



A unitload vehicle for delivering steel plates (blanks)

Pharmaceutical

AGVs are a preferred method of moving materials in the pharmaceutical industry. Because an AGV system tracks all movement provided by the AGVs, it supports process validation and cGMP (current Good Manufacturing Practice).

Chemical

AGVs deliver raw materials, move materials to curing storage warehouses, and provide transportation to other processing cells and stations. Common industries include rubber, plastics, and specialty chemicals.

Manufacturing

AGVs are often used in general manufacturing of products. AGVs can typically be found delivering raw materials, transporting work-in process, moving finished goods, removing scrap materials, and supplying packaging materials.

Automotive

AGV installations are found in Stamping Plants, Power Train (Engine and Transmission) Plants, and Assembly Plants delivering raw materials, transporting work-in process, and

moving finished goods. AGVs are also used to supply specialized tooling which must be changed.



A Tugger AGV pulling wheeled carts containing automotive body panels



Supplying a bin of parts for assembly onto cars

Paper and Print

AGVs can move paper rolls, pallets, and waste bins to provide all routine material movement in the production and warehousing (storage/retrieval) of paper, newspaper, printing, corrugating, converting, and plastic film.

Food and Beverage

AGVs can be applied to move materials in food processing (such as the loading of food and/or trays into sterilizers) and at the “end of line,” linking the palletizer, stretch wrapper, and the warehouse. AGVs can load standard, over-the-road trailers with finished goods, and unload trailers to supply raw materials or packaging materials to the plant. AGVs can also store and retrieve pallets in the warehouse.

Hospital

AGVs are becoming increasingly popular in the healthcare industry for efficient transport, and are programmed to be fully integrated to automatically operate doors, elevators/lifts, cart washers, trash dumpers, etc. AGVs typically move linens, trash, regulated medical waste, patient meals, soiled food trays, and surgical case carts.

Warehousing

Battery Charging

AGVs utilize a number of battery charging options. Each option is dependent on the users preference. The most commonly used battery charging technologies are *Battery Swap*, *Automatic/Opportunity Charging*, and *Automatic Battery Swap*.

Battery Swap



"*Battery swap technology*" requires an operator to manually remove the discharged battery from the AGV and place a fully charged battery in its place approximately 8 – 12 hours (about one shift) of AGVs operation. 5 – 10 minutes is required to perform this with each AGV in the fleet.

Automatic / Opportunity Charging



"Automatic and opportunity battery charging" allows for continuous operation. On average an AGV charges for 12 minutes every hour for automatic charging and no manual intervention is required. If opportunity is being utilized the AGV will receive a charge whenever the opportunity arises. When a battery pack gets to a predetermined level the AGV will finish the current job that it has been assigned before it goes to the charging station.

Automatic Battery Swap



"Automatic battery swap" is an alternative to manual battery swap. It requires an additional piece of automation machinery, an automatic battery changer, to the overall AGV system. AGVs will pull up to the battery swap station and have their batteries automatically replaced with fully charged batteries. The automatic battery changer then places the removed batteries into a charging slot for automatic recharging. The automatic battery changer keeps track of the batteries in the system and pulls them only when they are fully charged.

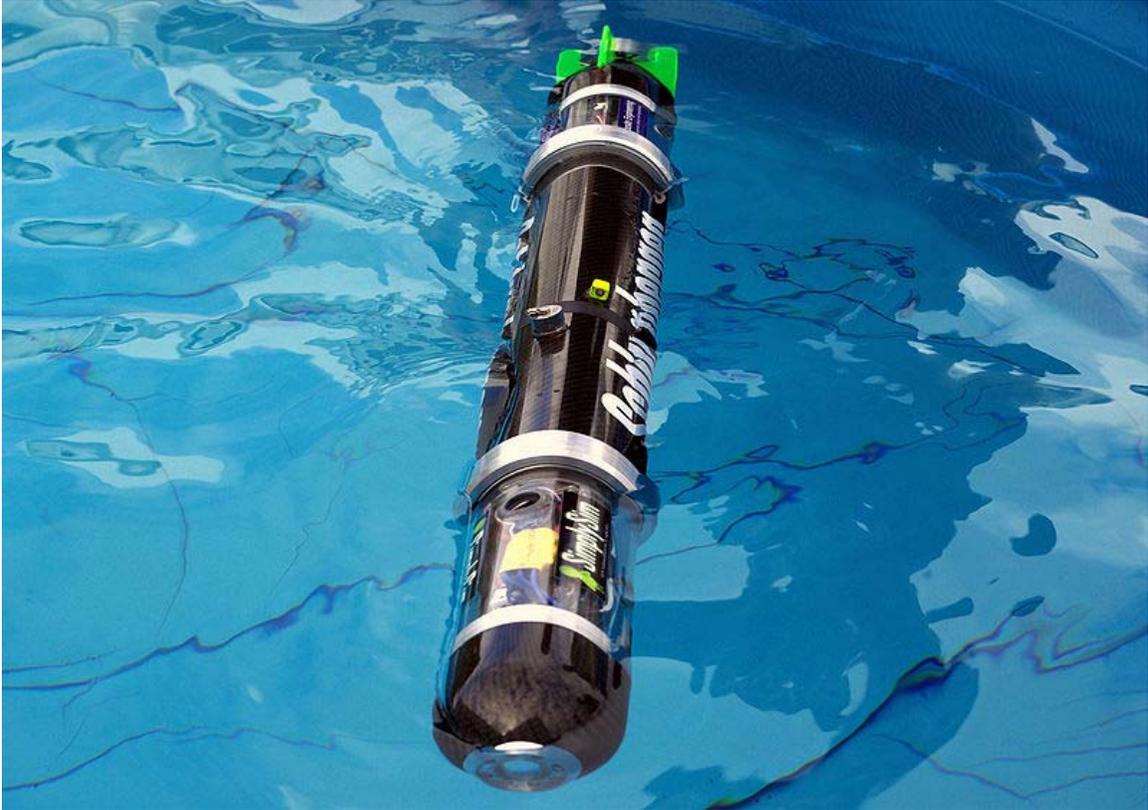
While a battery swap system reduces the manpower required to swap batteries, recent developments in battery charging technology allow batteries to be charged more quickly and efficiently potentially eliminating the need to swap batteries.

Chapter- 6

Autonomous Underwater Vehicle



Picture taken from the HSV Swift by an employee of Bluefin Robotics Corporation during a US Navy exercise.



The Blackghost AUV is designed to undertake an underwater assault course autonomously with no outside control.

An **autonomous underwater vehicle (AUV)** is a robot which travels underwater. In military applications, AUVs are also known as **unmanned undersea vehicles (UUVs)**. AUVs constitute part of a larger group of undersea systems known as unmanned underwater vehicles, a classification that includes non-autonomous remotely operated underwater vehicles (ROVs) – controlled and powered from the surface by an operator/pilot via an umbilical.

History

The first AUV was developed at the Applied Physics Laboratory at the University of Washington as early as 1957 by Stan Murphy, Bob Francois and later on, Terry Ewart. The "Special Purpose Underwater Research Vehicle", or SPURV, was used to study diffusion, acoustic transmission, and submarine wakes.

Other early AUVs were developed at the Massachusetts Institute of Technology in the 1970s. One of these is on display in the Hart Nautical Gallery in MIT. At the same time, AUVs were also developed in the Soviet Union (although this was not commonly known until much later).

Applications

Until relatively recently, AUVs have been used for a limited number of tasks dictated by the technology available. With the development of more advanced processing capabilities and high yield power supplies, AUVs are now being used for more and more tasks with roles and missions constantly evolving.

Commercial

The oil and gas industry uses AUVs to make detailed maps of the seafloor before they start building subsea infrastructure; pipelines and sub sea completions can be installed in the most cost effective manner with minimum disruption to the environment. The AUV allows survey companies to conduct precise surveys or areas where traditional bathymetric surveys would be less effective or too costly. Also, post-lay pipe surveys are now possible.

Military



Picture of the Pluto Plus, designed for remote minehunting and destruction by the company of Milan, Italy.

A typical military mission for an AUV is to map an area to determine if there are any mines, or to monitor a protected area (such as a harbor) for new unidentified objects.

AUVs are also employed in anti-submarine warfare, to aid in the detection of manned submarines.

Research

Scientists use AUVs to study lakes, the ocean, and the ocean floor. A variety of sensors can be affixed to AUVs to measure the concentration of various elements or compounds, the absorption or reflection of light, and the presence of microscopic life.

Hobby

Many roboticists construct AUVs as a hobby. A simple AUV can be constructed for around US\$99, consisting of a simple PVC pipe body and two or three waterproof motors with model airplane propellers. These AUVs can be fitted with a camera, lights and sonar like their commercial brethren, though usually their operational depth is around 50 to 100 feet, compared to the several-thousand-foot-depth capacity of some commercial models. They also tend to be less durable and are usually not oceangoing, being operated most of the time in pools or lakebeds. Several competitions exist which pit homemade AUVs against various objectives.

Vehicle designs



Bluefin-12 AUV with a Buried Object Scanning Sonar (BOSS) integrated in two wings. This picture was taken in January 2005 off the coast of Florida during engineering trials.

Hundreds of different AUVs have been designed over the past 50 or so years, but only a few companies sell vehicles in any significant numbers. There are about 10 companies that sell AUVs on the international market, including Kongsberg Maritime, Hydroid (now owned by Kongsberg), Bluefin Robotics, International Submarine Engineering Ltd. and Hafmynd.

Vehicles range in size from man portable lightweight AUVs to large diameter vehicles of over 10 metres length. Once popular amongst the military and commercial sectors, the smaller vehicles are now losing popularity. It has been widely accepted by commercial organizations that to achieve the ranges and endurances required to optimize the efficiencies of operating AUVs a larger vehicle is required. However, smaller, lightweight and less expensive AUVs are still common as a budget option for universities.

Some manufacturers have benefited from domestic government sponsorship including Bluefin and Kongsberg. The market is effectively split into three areas: scientific (including universities and research agencies), commercial offshore (oil and gas etc.) and military application (mine countermeasures, battle space preparation). The majority of these roles utilize a similar design and operate in a cruise mode. They collect data while following a preplanned route at speeds between 1 and 4 knots.

Commercially available AUVS include various designs such as the small REMUS 100 AUV developed by Woods Hole Oceanographic Institution in the US and now marketed by Hydroid, Inc.; the larger HUGIN 1000 and 3000 AUVs developed by Kongsberg Maritime and Norwegian Defence Research Establishment; the Bluefin Robotics 12-and-21-inch-diameter (300 and 530 mm) vehicles and the International Submarine Engineering Ltd. Explorer. Most AUVs follow the traditional torpedo shape as this is seen as the best compromise between size, usable volume, hydrodynamic efficiency and ease of handling. There are some vehicles that make use of a modular design, enabling components to be changed easily by the operators.

The market is evolving and designs are now following commercial requirements rather than being purely developmental. The next stage is likely to be a hybrid AUV/ROV that is capable of surveys and light intervention tasks. This requires more control and the ability to hover. Again, the market will be driven by financial requirements and the aim to save money and expensive ship time.

Today, while most AUVs are capable of unsupervised missions most operators remain within range of acoustic telemetry systems in order to maintain a close watch on their investment. This is not always possible. For example, Canada has recently taken delivery of two AUVs (ISE Explorers) to survey the sea floor underneath the Arctic ice in support of their claim under Article 76 of the United Nations Convention of the Law of the Sea. Also, ultra-low-power, long-range variants such as underwater gliders are becoming

capable of operating unattended for weeks or months in littoral and open ocean areas, periodically relaying data by satellite to shore, before returning to be picked up.

As of 2008, a new class of AUVs are being developed, which mimic designs found in nature. Although most are currently in their experimental stages, these biomimetic (or bionic) vehicles are able to achieve higher degrees of efficiency in propulsion and maneuverability by copying successful designs in nature. Two such vehicles are Festo's AquaJelly and Evologics' Bionik Manta.

Sensors

Primarily oceanographic tools, AUVs carry sensors to navigate autonomously and map features of the ocean. Typical sensors include compasses, depth sensors, sidescan and other sonars, magnetometers, thermistors and conductivity probes. A demonstration at Monterey Bay in California in September 2006 showed that a 21-inch (530 mm) diameter AUV can tow a 300 feet (91 m) long hydrophone array while maintaining a 3-knot (5.6 km/h) cruising speed.¹²

Navigation

AUVs can navigate using an underwater acoustic positioning system. When operating within a net of sea floor deployed baseline transponders this is known as LBL navigation. When a surface reference such as a support ship is available, ultra-short baseline (USBL) or short-baseline (SBL) positioning is used to calculate where the subsea vehicle is relative to the known (GPS) position of the surface craft by means of acoustic range and bearing measurements. When it is operating completely autonomously, the AUV will surface and take its own GPS fix. Between position fixes and for precise maneuvering, an inertial navigation system on board the AUV measures the acceleration of the vehicle and Doppler velocity technology is used to measure rate of travel. A pressure sensor measures the vertical position. These observations are filtered to determine a final navigation solution. An emerging alternative is using an inertial navigation system in conjunction with either a GPS receiver, or an additional magnetic compass for Dead Reckoning whenever the GPS signal is lost.

Power

Most AUVs in use today are powered by rechargeable batteries (lithium ion, lithium polymer, nickel metal hydride etc), and are implemented with some form of Battery Management System. Some vehicles use primary batteries which provide perhaps twice the endurance—at a substantial extra cost per mission. A few of the larger vehicles are powered by aluminum based semi-fuel cells, but these require substantial maintenance, require expensive refills and produce waste product that must be handled safely. An emerging trend is to combine different battery and power systems with Ultra-capacitors.

Underwater glider



NOAA Personnel launch a *Slocum* Glider off Florida



Rutgers Slocum Glider RU02 deployed in Sargasso Sea



Dr. Bruce Howe and Bill Felton of University of Washington prepare a Seaglider for deployment



UW Seaglider at the surface between dives

An **underwater glider** is a type of autonomous underwater vehicle (AUV) that uses small changes in its buoyancy in conjunction with wings to convert vertical motion to horizontal, and thereby propel itself forward with very low power consumption. While not as fast as conventional AUVs, gliders using buoyancy-based propulsion represent a significant increase in range and duration compared to vehicles propelled by electric motor-driven propellers, extending ocean sampling missions from hours to weeks or months, and to thousands of kilometers of range. Gliders follow an up-and-down, sawtooth-like profile through the water, providing data on temporal and spatial scales unavailable to previous AUVs, and much more costly to sample using traditional shipboard techniques.

History

The DARPA SBIR program received a proposal for a temperature gradient glider in 1988. DARPA was aware at that time of similar research projects underway in the USSR.

The concept of the glider was introduced to the oceanographic community by Henry Stommel in a 1989 article in *Oceanography*, when he proposed a glider concept called *Slocum*, developed with research engineer Doug Webb. They named the glider after Joshua Slocum, who made the first solo circumnavigation of the globe by sailboat. They proposed harnessing energy from the thermal gradient between deep ocean water (2-4 °C) and surface water (near atmospheric temperature) to achieve globe-circling range, constrained only by battery power onboard for communications, sensors, and navigational computers.

By 2005, not only had a working thermal-powered glider (*Slocum Thermal*) been demonstrated by Webb Research (founded by Doug Webb), but they and other institutions had introduced battery-powered gliders with impressive duration and efficiency, far exceeding that of traditional survey-class AUVs. The University of Washington *Seaglider* and Scripps Institution of Oceanography *Spray* vehicles have performed feats such as crossing the Gulf Stream from the mainland USA to Bermuda, and, together with the Webb *Slocum*, conducting sustained, multi-vehicle collaborative monitoring of oceanographic variables in Monterey Bay.

Originally conceived as testbed for the thermal-power gliders before developing into a platform of their own, the Webb Slocum electric gliders have been widely deployed since 2003. On December 4, 2009, one of these gliders, RU-27, became the first to complete a transatlantic journey, traveling from New Jersey to the coast of Spain in 221 days. The effort was led by a team from Rutgers University, which has become one of the largest glider operators.

Functional Description

Glider typically make measurements such as temperature, conductivity (to calculate salinity), currents, chlorophyll fluorescence, optical backscatter, bottom depth, and (occasionally) acoustic backscatter. They navigate with the help of periodic surface GPS fixes, pressure sensors, tilt sensors, and magnetic compasses. Vehicle pitch is controllable by movable internal ballast (usually battery packs), and steering is accomplished either with a rudder (as in *Slocum*) or by moving internal ballast to control roll (as in *Spray* and *Seaglider*). Buoyancy is adjusted either by using a piston to flood/evacuate a compartment with seawater (*Slocum*) or by moving oil in/out of an external bladder (*Seaglider*, *Spray*, and *Slocum Thermal*). Commands and data are relayed between gliders and shore by satellite.

Glider vary in the pressure they are able to withstand. The coastal *Slocum* model is rated for 200 meters depth. *Spray* can operate to 1500 meters, *Seaglider* to 1000 meters, *SeaExplorer* to 700, and *Slocum Thermal* to 1200. In August 2010, a *Deep Glider* variant of the *Seaglider* achieved a repeated 6000-meter operating depth.

XRay Flying Wing

As of 2006, the US Navy Office of Naval Research is developing the world's largest glider, the Liberdade XRay, which uses a blended wing body hullform to achieve hydrodynamic efficiency. It is intended to quietly track diesel electric submarines in littoral waters, remaining on station for up to 6 months, with major field testing beginning in August 2006.

Chapter- 7

Gynoid

The term **gynoid** has been applied to a humanoid robot designed to look like a human female; it has been derived from the word android in response to its linguistically masculine lexical element *andro-*, which is perceived as implying a male-styled robot according to some cultural readings.

Gynoid has not gained popularity, however, with the term **android** being used almost universally to refer to robotic humanoids regardless of apparent gender. The term gynoid was used by Gwyneth Jones in her 1985 novel *Divine Endurance* to describe a robot slave character in a futuristic China, that is judged by her beauty.

The tongue-in-cheek portmanteau **fembot** (female robot) was used in the Austin Powers films. **Robotess** is the oldest gender-specific term, originating in 1921 from the same source as robot.



An Actroid at Expo 2005 in Aichi

In real life

Female-appearing robots have also appeared in real-life, with early constructions being crude. The first gynoid was produced by Sex Objects Ltd, a British company, for use as a "sex-aid". It was called simply "36C", from her chest measurement, and had a 16-bit microprocessor and voice synthesiser that allowed primitive responses to speech and push button inputs. Later examples include:

- Project Aiko, an attempt at producing a realistic-looking female android. It speaks Japanese and English and has been produced for a price of 13000 euro

EveR-1



EveR-1, the world's second female android, can express human emotions and have a conversation in Korean and English.

EveR-1 (Korean: 에버원) is a female android, developed by a team of South Korean scientists from the Korea Institute of Industrial Technology in Korea University of Science and Technology. The project is headed by Baeg Moon-hong (Korean: 백문홍) and was unveiled to the public at Kyoyuk MunHwa HoeKwan in Seoul on May 4, 2006. Its name is derived from the combination of the Biblical "Eve" and the *r* from *robot*.

EveR-1

EveR-1 is a direct competitor of Actroid, which is being developed by Kokoro Dreams and Osaka University of Japan, and was unveiled at the International Robot Exhibition in Tokyo in 2003. EveR-1 was built in a year at a cost of 300 million won (US\$321,000) in state funds.

The creators said the humanoid's face is a composite of two well-known Korean actresses, while the torso is based on a singer, though the names of the celebrities were not revealed. The android weighs 50 kilograms and has a height of 160 centimeters.

The creators also said that EveR-1 can mimic the human emotions of happiness, sadness, anger, and surprise more naturally than its Japanese rival, while using a hydraulic system for certain movements. EveR-1 contains a total of 35 miniature motors located throughout its upper body, which enables EveR-1 to move its head, arms, and upper body and even move its lips in synchronization with the robot's speech. Its skin is made of synthetic, pliable silicone jelly that feels similar to human skin.

The android can recognize 400 Korean and English words, allowing it to respond to questions both verbally and through 15 facial expressions: EveR-1 will show displeasure if you poke her. The android also has motion data process sensors in its artificial eyes, enabling it to follow people with its eyes and head.

EveR-2



EveR-2 is more advanced than its predecessor, and is the first android to have the ability to sing.

EveR-2 is the successor of EveR-1, which performed at Robot World 2006 in Seoul, has improved vision and ability to express emotions, as well as various other enhancements. Boredom is now an available emotion, along with the usual joy, anger, sorrow, and happiness. She sang the Korean ballad "I Will Close My Eyes For You" during the

opening ceremony at the Robot World 2006 conference in Seoul, which made her the first android singer.

She is about 5'7" (170 cm) tall and weighs about 135 pounds (60 kg). Her silicone-covered face has a higher flexibility; 29 motors and dozens of joints provide 23 degrees of freedom for self-expression. In total, EveR-2 has 25 more degrees of freedom than EveR-1. Her improved speech recognition, voice synthesis and gesture expression technology allows for more sophisticated communication and interaction with humans. The small CCD cameras of EveR-1 have been upgraded to Wide range Small CCD cameras (90 degrees) for better vision. While the synthetic pliable silicone jelly only covered the face and hand with soft materials of the EveR-1 (while the rest was covered with hard material), EveR-2 has her whole body covered with the soft artificial skin.

Baek Moon-hong envisions educational and entertainment functions for the androids, from providing information in department stores and museums, to reading stories to children.

Future models

KITECH is currently developing EveR-3 and EveR-4, scheduled for release in 2010. The upgraded female androids are expected to walk, sing, dance, and have "substantially improved intelligence."

A male version is also currently being developed.

Actroid



Repliee Q2 can mimic such human functions as blinking, breathing and speaking, with the ability to recognize and process speech and touch, and then respond in kind.

An **Actroid** is a humanoid robot and android with strong visual human-likeness developed by Osaka University and manufactured by Kokoro Company Ltd. (the animatronics division of Sanrio). It was first unveiled at the 2003 International Robot Exhibition in Tokyo, Japan. Several different versions of the product have been produced since then. In most cases, the robot's appearance has been modeled after an average young woman of Japanese descent.

The Actroid woman is a pioneer example of a real machine similar to imagined machines called by the science fiction terms *android* or *gynoid*, so far used only for fictional robots. It can mimic such lifelike functions as blinking, speaking, and breathing. The "Repliee"

models are interactive robots with the ability to recognise and process speech and respond in kind.

Technology

Internal sensors allow Actroid models to react with a natural appearance by way of air actuators placed at many points of articulation in the upper body. Early models had 42 points of articulation, later models have 47. So far, movement in the lower body is limited. The operation of the robot's sensory system in tandem with its air powered movements make it quick enough to react to or fend off intrusive motions, such as a slap or a poke. Artificial intelligence possessed by the android gives it the ability to react differently to more gentle kinds of touch, such as a pat on the arm.

The Actroid can also imitate human-like behavior with slight shifts in position, head and eye movements and the appearance of breathing in its chest. Additionally, the robot can be "taught" to imitate human movements by facing a person who is wearing reflective dots at key points on their body. By tracking the dots with its visual system and computing limb and joint movements to match what it sees, this motion can then be "learned" by the robot and repeated.

The skin is composed of silicone and appears highly realistic. The compressed air that powers the robot's servo motors, and most of the computer hardware that operates the A.I., are external to the unit. This is a contributing factor to the robot's lack of locomotion capabilities. When displayed, the Actroid has always been either seated or standing with firm support from behind.

The interactive Actroids can also communicate on a rudimentary level with humans by speaking. Microphones within those Actroids record the speech of a human, and this sound is then filtered to remove background noise - including the sounds of the robot's own operation. Speech recognition software is then used to convert the audio stream into words and sentences, which can then be processed by the Actroid's A.I. A verbal response is then given through speakers external to the unit.

Further interactivity is achieved through non-verbal methods. When addressed, the interactive Actroids use a combination of "floor sensors and omnidirectional vision sensors" in order to maintain eye contact with the speaker. In addition, the robots can respond in limited ways to body language and tone of voice by changing their own facial expressions, stance and vocal inflection.

Models

The original Repliee Q1 had a "sister" model, Repliee R1, which is modeled after a 5-year-old Japanese girl.

More advanced models were present at Expo 2005 in Aichi to help direct people to specific locations and events. Four unique visages were given to these robots. The Repliee Q1-expo was modeled after a presenter for NHK news. To make the face of the Repliee Q2 model, the faces of several young Japanese women were scanned and the images combined into an average composite face.

The newer model Actroid-DER2 made a recent tour of U.S. cities. At NextFest 2006, the robot spoke English and was displayed in a standing position and dressed in a black vinyl bodysuit. A different Actroid-DER2 was also shown in Japan around the same time. This new robot has more realistic features and movements than its predecessor.

In July 2006, another appearance was given to the robot. This model was built to look like its male co-creator, roboticist Hiroshi Ishiguro, and named Geminoid HI-1. Controlled by a motion-capture interface, Geminoid HI-1 can imitate Ishiguro's body and facial movements, and it can reproduce his voice in sync with his motion and posture. Ishiguro hopes to develop the robot's human-like presence to such a degree that he could use it to teach classes remotely, lecturing from home while the Geminoid interacts with his classes at Osaka University.

HRP-4C

The **HRP-4C** is a humanoid robot created by the National Institute of Advanced Industrial Science and Technology, a Japanese research facility, and publicly demonstrated on March 16, 2009. It is 158 cm (5 feet, 2 inches) tall and weighs 43 kg (95 pounds) including battery. Its shape and joints are based on the 1997–1998 Japanese body dimension database (though many have noted that the hands seem oversized). It is capable of recognizing ambient sounds and, by using the vocal synthesizer Vocaloid, can sing. Recent upgrades have allowed HRP-4C to mimic human facial and head movements as well as execute dance steps, resulting in the most human-like performance yet at Tokyo's Digital Content Expo in 2010. The HRP-4C is considered to be a gynoid.

Meinü robot

A **Meinü robot** is a Chinese gynoid model which was reported on in Chinese news sources in 2006. In Mandarin, Měinǚ Jīqìrén 美女机器人 literally means "beautiful-woman robot" and is officially translated "beauty robot". The first Meinü was later named **Miss Rong Cheng**.

The unit is capable of locomotion, using visual navigation to avoid obstacles, speech recognition, emotion recognition (whether audio or gestural is not stated), and speaking. The languages it uses are English, Mandarin and Sichuan dialect. It can tell jokes, sing songs, etc. It is intended for tour-guide applications, businesses and hotels, advertising, and possibly for TV-show hosting.

Rong Cheng was sent to the Sichuan Science and Technology Museum to be a receptionist or tour guide. The build cost was approximately 300,000 yuan (\$37,500), but

the inventors expect this can be reduced to a third of that if 100 are to be produced. Only one year of research was required to produce it, which suggests it builds on other projects.

It was worked on by 10 researchers from the Robot Research Center at the Institute of Automation of the Chinese Academy of Sciences, but it is very difficult to locate their academic papers. ChinaDaily's English edition named the principal designer as Li Chengrong, whereas Reuters and Sina English said it was Yue Hongqiang.

Female-appearing robots have also generated controversy. In 1983 a busty female robot named "Sweetheart" was removed from a display at Berkeley college after a petition was presented claiming it was insulting to women. The robot's creator, Clayton Bailey, a professor of art at California State University, called this "censorship" and "next to book burning."



“Sweetheart”, shown with its creator, Clayton Bailey; the busty female robot (also a functional coffee maker) that created a controversy when it was displayed at the Lawrence Hall of Science at Berkeley, UC

Functions

Gynoids may be "eroticized", and some examples such as Aiko include sensitivity sensors in their breasts and genitals to facilitate sexual response. The fetishization of gynoids in real life has been attributed to male desires for custom-made passive women, and has been compared to life-size sex dolls.

The reaction of people to robots that appeared female to different degrees has been studied. The reaction of people to such robots has been attributed in part to gender

stereotypes. This research has been used to elucidate gender cues, clarifying which behaviors and aesthetics elicit a stronger gender-induced response.

In fiction

Artificial women have been a common trope in fiction and mythology since the writings of the ancient Greeks. This has continued with modern fiction, particularly in the genre of science fiction. In science fiction, female-appearing robots are often produced for use as domestic servants and sexual slaves, as seen in the film *Westworld*, Paul McAuley's novel *Fairyland* (1995), and Lester del Rey's short story "Helen O'Loy" (1938), and sometimes as warriors, killers, or laborers.

Metaphors

Misogyny

The treatment of gynoids in fiction has been seen as a metaphor for misogyny, as in the film *Blade Runner*, in which all three of the important female characters are gynoids, two of whom use their sexuality to attempt to manipulate or kill the protagonist Rick Deckard, often using sexualised imagery, such as when Pris attempts to strangle him between her thighs. Daniel Dinello writes that the violence with which the gynoids are treated represents Deckard's hatred of women. The third gynoid, Rachel, acts as a submissive female, even after Deckard "virtually rapes her". Thomas Foster writes, about the novel *Dead Girls* by Richard Calder, that the technological bodies of gynoids depict sexism in an unnatural context, highlighting its negative impact. They also show that stereotypes and societal attitudes will not necessarily be altered through technological progress.

Japanese anime and manga both have a long tradition of female robot characters. The artist Hajime Sorayama is particularly influential, with his "sexy robot" images, found in his collection *The Gynoids* (1993). These pieces depict primarily females with metallic skin, and have been regarded as comments on gender and sexual conventions, and race, by highlighting the "whiteness" of the traditional pin-up girl. The sexualised images of gynoids have also been interpreted as fetishisation of the female body, racial differences, and technology.

Female freedom

Gynoids have also been used as a metaphor in feminist discourse, as part of cyborg feminism, representing female physical strength and freedom from the expectation to reproduce.

A long tradition exists in fiction, of men attempting to create the stereotypical ideal woman, and fictional gynoids have been seen as an extension of this theme. Examples include Hephaestus in the Iliad who created female servants of metal and Ilmarinen in the

Kalevala who created an artificial wife. Probably most famous, however, is Pygmalion, one of the earliest conceptualizations of constructions similar to gynoids in literary history, from Ovid's account of Pygmalion. In this myth a female statue is sculpted that is so beautiful that the creator falls in love with it, and after praying to Venus, the goddess takes pity on him and converts the statue into a real woman with whom Pygmalion has children.

The first gynoid in film, the *maschinenmensch* ("machine-human"), also called "Parody", "Futura", "Robotrix", or the "Maria impersonator", in Fritz Lang's *Metropolis* is also an example: a femininely shaped robot is given skin so that she is not known to be a robot and successfully impersonates the imprisoned Maria and works convincingly as an exotic dancer.

Such gynoids are designed according to patriarchal stereotypes of a perfect women, being "sexy, dumb, and obedient", and reflect the emotional frustration of their creators. Fictional gynoids are often unique products made to fit a particular man's desire, as seen in the novel *Tomorrow's Eve* and films *The Benumbed Woman*, *The Stepford Wives*, *Mannequin* and *Weird Science*, and the creators are often male "mad scientists" such as the characters Rotwang in *Metropolis*, Tyrell in *Blade Runner*, and the husbands in *The Stepford Wives*. Gynoids have been described as the "ultimate geek fantasy: a metal-and-plastic woman of your own".

The Bionic Woman television series coined the word fembot. These fembots were a line of powerful life-like gynoids with the faces of protagonist Jaime Sommers's best friends. They fought in two multi-part episodes of the series: "Kill Oscar" and "Fembot in Las Vegas", and despite the feminine prefix, there were also male versions, including some designed to impersonate particular individuals for the purpose of infiltration. While not truly artificially intelligent, the fembots still had extremely sophisticated programming that allowed them to pass for human in most situations. The term "fembot" was also used in *Buffy the Vampire Slayer* (referring to a robot duplicate of the title character, a.k.a. the Buffybot) and *Futurama*.

The 1987 science fiction cult movie *Cherry 2000* also portrayed a gynoid character which was described by the male protagonist as his "perfect partner". The 1964 TV series *My Living Doll* features a robot, portrayed by Julie Newmar, who is similarly described.

Sex objects

Some argue that gynoids have often been portrayed as sexual objects. Female cyborgs have been similarly used in fiction, in which natural bodies are modified to become objects of fantasy. The female robot in visual media has been described as "the most visible linkage of technology and sex" by Steven Heller.

Feminist critic Patricia Melzer writes in *Alien Constructions: Science Fiction and Feminist Thought* that gynoids in Richard Calder's *Dead Girls* are inextricably linked to men's lust, and are mainly designed as sex-objects, having no use beyond "pleasing men's

violent sexual desires". The gynoid character Eve from the film *Eve of Destruction* has been described as "a literal sex bomb", with her subservience to patriarchal authority and a bomb in place of reproductive organs. In the film *The Perfect Women*, the titular robot Olga is described as having "no sex", but Steve Chibnall writes in his essay "Alien Women" in *British Science Fiction Cinema* that it is clear from her fetishistic underwear that she is produced as a toy for men, with an "implicit fantasy of a fully compliant sex machine".

Sex with gynoids has been compared to necrophilia. Sexual interest in gynoids and fembots has been attributed to fetishisation of technology, and compared to Sadoomasochism in that it reorganizes the social risk of sex. The depiction of female robots minimizes the threat felt by men from female sexuality and allow the "erasure of any social interference in the spectator's erotic enjoyment of the image". Gynoid fantasies are produced and collected by online communities centered around chat rooms and website galleries, such as Doll Forum and Gynoid Gallery.

Isaac Asimov writes that his robots were generally sexually neutral, and that giving the majority masculine names was not an attempt to comment on gender. He first wrote about female-appearing robots at the request of editor Judy-Lynn del Rey. Asimov's short story "Feminine Intuition" (1969) is an early example that showed gynoids as being as capable and versatile as male robots, with no sexual connotations. Early models in "Feminine Intuition" were "female caricatures", used to highlight their human creators' reactions to the idea of female robots. Later models lost obviously feminine features, but retained "an air of femininity".

Gender

Fiction about gynoids or female cyborgs reinforce essentialist ideas of femininity, according to Magret Grebowicz. Such essentialist ideas may present as sexual or gender stereotypes. Among the few non-eroticized fictional gynoids include Rosie the Robot Maid from *The Jetsons*. However, she still has some stereotypically feminine qualities, such as a matronly shape and a predisposition to cry.



Exaggeratedly feminine Fembots with guns in their breasts, from *Austin Powers: International Man Of Mystery*

The stereotypical role of wifedom has also been explored through use of gynoids. In *The Stepford Wives*, husbands are shown as desiring to restrict the independence of their wives, and obedient and stereotypical spouses are preferred. The husbands' technological method of obtaining this "perfect wife" is through the murder of their human wives and replacement with gynoid substitutes that are compliant and housework obsessed, resulting in a "picture-postcard" perfect suburban society. This has been seen as an allegory of male chauvinism of the period, by representing marriage as a master-slave relationship, and an attempt at raising feminist consciousness during the era of second wave feminism.

In a parody of the fembots from *The Bionic Woman*, attractive fembots in fuzzy see-through night-gowns were used as a lure for the fictional agent Austin Powers in the movie *Austin Powers: International Man Of Mystery*. The film's sequels had cameo appearances of characters revealed as fembots.

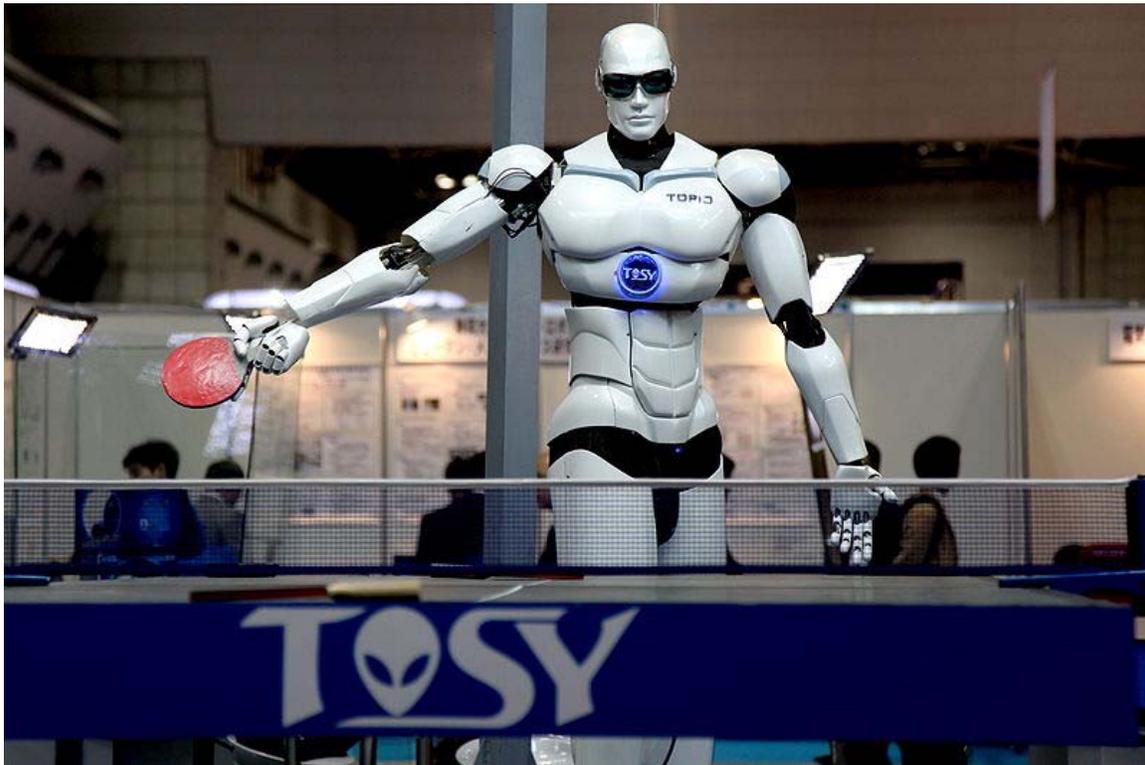
Judith Halberstam writes that these gynoids inform the viewer that femaleness does not indicate naturalness, and their exaggerated femininity and sexuality is used in a similar way to the title character's exaggerated masculinity, lampooning stereotypes.

Chapter- 8

Humanoid Robot

A **humanoid robot** is a robot with its overall appearance, based on that of the human body, allowing interaction with made-for-human tools or environments. In general humanoid robots have a torso with a head, two arms and two legs, although some forms of humanoid robots may model only part of the body, for example, from the waist up. Some humanoid robots may also have a 'face', with 'eyes' and 'mouth'. Androids are humanoid robots built to aesthetically resemble a human.

Introduction



TOSY's TOPIO, a humanoid robot, can play ping pong.

A humanoid robot is an autonomous robot because it can adapt to changes in its environment or itself and continue to reach its goal. This is the main difference between humanoid and other kinds of robots. In this context, some of the capacities of a humanoid robot may include, among others:

- self-maintenance (like recharging itself)
- autonomous learning (learn or gain new capabilities without outside assistance, adjust strategies based on the surroundings and adapt to new situations)
- avoiding harmful situations to people, property, and itself
- safe interacting with human beings and the environment

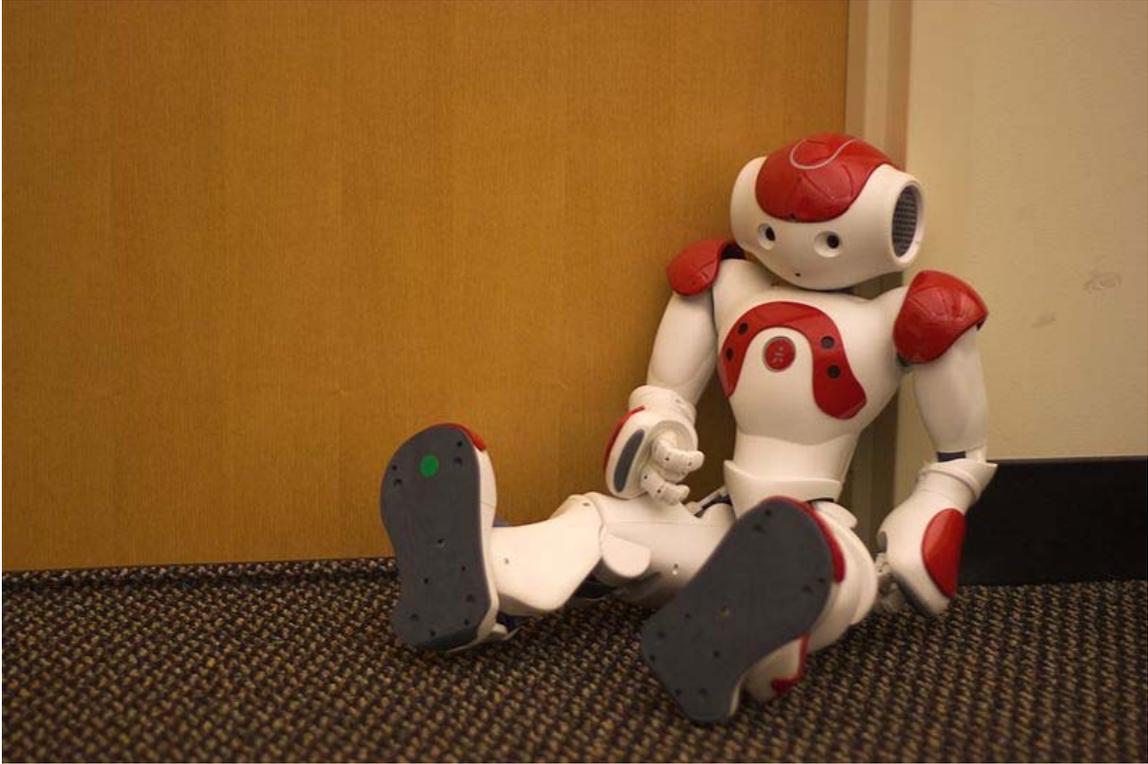
Like other mechanical robots, humanoid refer to the following basic components too: Sensing, Actuating and Planning and Control. Since they try to simulate the human structure and behavior and they are autonomous systems, most of the times humanoid robots are more complex than other kinds of robots.

This complexity affects all robotic scales (mechanical, spatial, time, power density, system and computational complexity), but it is more noticeable on power density and system complexity scales. In the first place, most current humanoids aren't strong enough even to jump and this happens because the power/weight ratio is not as good as in the human body. The dynamically balancing *Dexter* can jump, but poorly so far. On the other hand, there are very good algorithms for the several areas of humanoid construction, but it is very difficult to merge all of them into one efficient system (the system complexity is very high). Nowadays, these are the main difficulties that humanoid robots development has to deal with.

Humanoid robots are created to imitate some of the same physical and mental tasks that humans undergo daily. Scientists and specialists from many different fields including engineering, cognitive science, and linguistics combine their efforts to create a robot as human-like as possible. Their creators' goal for the robot is that one day it will be able to both understand human intelligence, reason and act like humans. If humanoids are able to do so, they could eventually work in cohesion with humans to create a more productive and higher quality future. Another important benefit of developing androids is to understand the human body's biological and mental processes, from the seemingly simple act of walking to the concepts of consciousness and spirituality.

There are currently two ways to model a humanoid robot. The first one models the robot like a set of rigid links, which are connected with joints. This kind of structure is similar to the one that can be found in industrial robots. Although this approach is used for most of the humanoid robots, a new one is emerging in some research works that use the knowledge acquired on biomechanics. In this one, the humanoid robot's bottom line is a resemblance of the human skeleton.

Purpose



Nao (robot) is a robot created for companionship. It also competes in the RoboCup soccer championship.



Enon was created to be a personal assistant. It is self-guiding and has limited speech recognition and synthesis. It can also carry things.

Humanoid robots are used as a research tool in several scientific areas.

Researchers need to understand the human body structure and behavior (biomechanics) to build and study humanoid robots. On the other side, the attempt to simulate the human body leads to a better understanding of it.

Human cognition is a field of study which is focused on how humans learn from sensory information in order to acquire perceptual and motor skills. This knowledge is used to develop computational models of human behavior and it has been improving over time.

It has been suggested that very advanced robotics will facilitate the enhancement of ordinary humans.

Although the initial aim of humanoid research was to build better orthosis and prosthesis for human beings, knowledge has been transferred between both disciplines. A few examples are: powered leg prosthesis for neuromuscularly impaired, ankle-foot orthosis, biological realistic leg prosthesis and forearm prosthesis.

Besides the research, humanoid robots are being developed to perform human tasks like personal assistance, where they should be able to assist the sick and elderly, and dirty or dangerous jobs. Regular jobs like being a receptionist or a worker of an automotive manufacturing line are also suitable for humanoids. In essence, since they can use tools and operate equipment and vehicles designed for the human form, humanoids could theoretically perform any task a human being can, so long as they have the proper software. However, the complexity of doing so is deceptively great.

They are becoming increasingly popular for providing entertainment too. For example, Ursula, a female robot, sings, dances, and speaks to her audiences at Universal Studios. Several Disney attractions employ the use of animatrons, robots that look, move, and speak much like human beings, in some of their theme park shows. These animatrons look so realistic that it can be hard to decipher from a distance whether or not they are actually human. Although they have a realistic look, they have no cognition or physical autonomy.

Humanoid robots, especially with artificial intelligence algorithms, could be useful for future dangerous and/or distant space exploration missions, without having the need to turn back around again and return to Earth once the mission is completed.

Sensors

A sensor is a device that measures some attribute of the world. Being one of the three primitives of robotics (besides planning and control), sensing plays an important role in robotic paradigms.

Sensors can be classified according to the physical process with which they work or according to the type of measurement information that they give as output. In this case, the second approach was used.

Proprioceptive Sensors

Proprioceptive sensors sense the position, the orientation and the speed of the humanoid's body and joints.

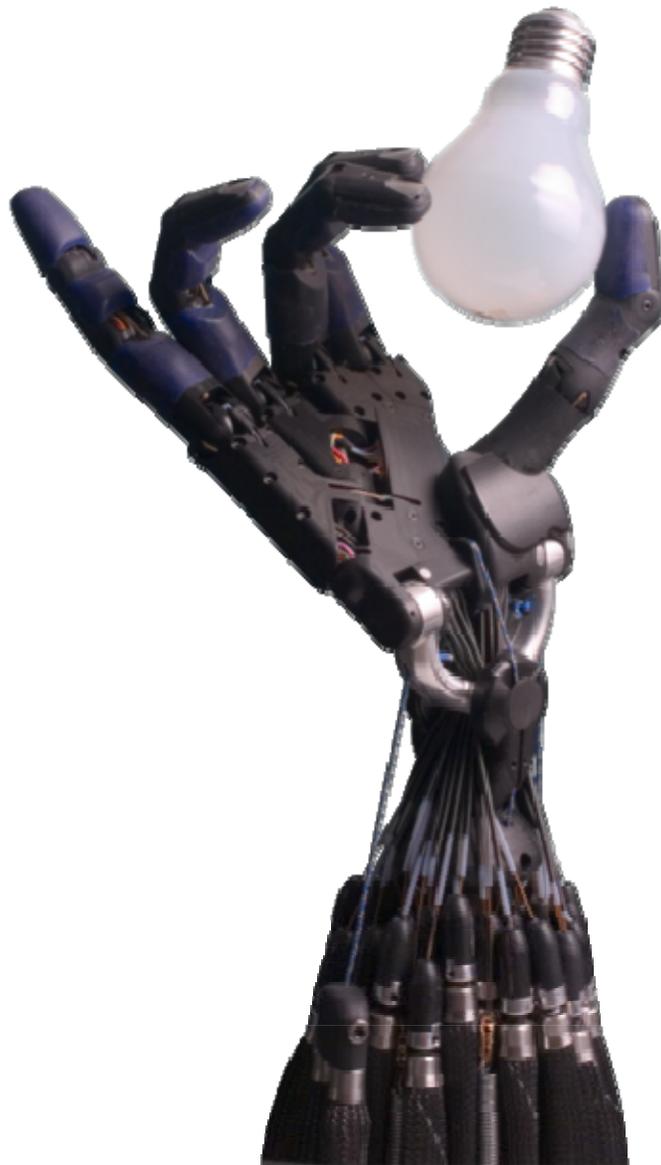
In human beings inner ears are used to maintain balance and orientation. Humanoid robots use accelerometers to measure the acceleration, from which velocity can be calculated by integration; tilt sensors to measure inclination; force sensors placed in

robot's hands and feet to measure contact force with environment; position sensors, that indicate the actual position of the robot (from which the velocity can be calculated by derivation) or even speed sensors.

Exteroceptive Sensors

Exteroceptive sensors give the robot information about the surrounding environment allowing the robot to interact with the world. The exteroceptive sensors are classified according to their functionality.

Proximity sensors are used to measure the relative distance (range) between the sensor and objects in the environment. They perform the same task that vision and tactile senses do in human beings. There are other kinds of proximity measurements, like laser ranging, the usage of stereo cameras, or the projection of a colored line, grid or pattern of dots to observe how the pattern is distorted by the environment. To sense proximity, humanoid robots can use sonars and infrared sensors, or tactile sensors like bump sensors, whiskers (or feelers), capacitive and piezoresistive sensors.



An artificial hand holding a lightbulb.

Arrays of tactels can be used to provide data on what has been touched. The Shadow Hand uses an array of 34 tactels arranged beneath its polyurethane skin on each finger tip. Tactile sensors also provide information about forces and torques transferred between the robot and other objects.

Vision refers to processing data from any modality which uses the electromagnetic spectrum to produce an image. In humanoid robots it is used to recognize objects and determine their properties. Vision sensors work most similarly to the eyes of human beings. Most humanoid robots use CCD cameras as vision sensors.

Sound sensors allow humanoid robots to hear speech and environmental sounds, and perform as the ears of the human being. Microphones are usually used for this task.

Actuators

Actuators are the motors responsible for motion in the robot.

Humanoid robots are constructed in such a way that they mimic the human body, so they use actuators that perform like muscles and joints, though with a different structure. To achieve the same effect as human motion, humanoid robots use mainly rotary actuators. They can be either electric, pneumatic, hydraulic, piezoelectric or ultrasonic.

Hydraulic and electric actuators have a very rigid behavior and can only be made to act in a compliant manner through the use of relatively complex feedback control strategies . While electric coreless motor actuators are better suited for high speed and low load applications, hydraulic ones operate well at low speed and high load applications.

Piezoelectric actuators generate a small movement with a high force capability when voltage is applied. They can be used for ultra-precise positioning and for generating and handling high forces or pressures in static or dynamic situations.

Ultrasonic actuators are designed to produce movements in a micrometer order at ultrasonic frequencies (over 20 kHz). They are useful for controlling vibration, positioning applications and quick switching.

Pneumatic actuators operate on the basis of gas compressibility. As they are inflated, they expand along the axis, and as they deflate, they contract. If one end is fixed, the other will move in a linear trajectory. These actuators are intended for low speed and low/medium load applications. Between pneumatic actuators there are: cylinders, bellows, pneumatic engines, pneumatic stepper motors and pneumatic artificial muscles.

Planning and Control

In planning and control the essential difference between humanoids and other kinds of robots (like industrial ones) is that the movement of the robot has to be human-like, using legged locomotion, especially biped gait. The ideal planning for humanoid movements during normal walking should result in minimum energy consumption, like it happens in the human body. For this reason, studies on dynamics and control of these kinds of structures become more and more important.

To maintain dynamic balance during the walk, a robot needs information about contact force and its current and desired motion. The solution to this problem relies on a major concept, the Zero Moment Point (ZMP).

Another characteristic about humanoid robots is that they move, gather information (using sensors) on the "real world" and interact with it, they don't stay still like factory manipulators and other robots that work in highly structured environments. Planning and Control have to focus about self-collision detection, path planning and obstacle avoidance to allow humanoids to move in complex environments.

There are features in the human body that can't be found in humanoids yet. They include structures with variable flexibility, which provide safety (to the robot itself and to the people), and redundancy of movements, i.e., more degrees of freedom and therefore wide task availability. Although these characteristics are desirable to humanoid robots, they will bring more complexity and new problems to planning and control.

Timeline of developments

c. 250 BC

The *Lie Zi* described an automaton.

c. 50 AD

Greek mathematician Hero of Alexandria described a machine to automatically pour wine for party guests.

1206

Al-Jazari described a band made up of humanoid automata which, according to Charles B. Fowler, performed "more than fifty facial and body actions during each musical selection." Al-Jazari also created hand washing automata with automatic humanoid servants, and an elephant clock incorporating an automatic humanoid mahout striking a cymbal on the half-hour. His programmable "castle clock" also featured five musician automata which automatically played music when moved by levers operated by a hidden camshaft attached to a water wheel.

1495

Leonardo da Vinci designs a humanoid automaton that looks like an armored knight, known as Leonardo's robot.

1738

Jacques de Vaucanson builds The Flute Player, a life-size figure of a shepherd that could play twelve songs on the flute and The Tambourine Player that played a flute and a drum or tambourine.

1774

Pierre Jaquet-Droz and his son Henri-Louis created the Draughtsman, the Musicienne and the Writer, a figure of a boy that could write messages up to 40 characters long.

1837

The story of the Golem of Prague, an humanoid artificial intelligence activated by inscribing Hebrew letters on its forehead, based on Jewish folklore, was created by Jewish German writer Berthold Auerbach for his novel *Spinoza*.

1921

Czech writer Karel Čapek introduced the word "robot" in his play *R.U.R. (Rossum's Universal Robots)*. The word "robot" comes from the word "robota", meaning, in Czech, "forced labour, drudgery".

1927

The Maschinenmensch ("machine-human"), a gynoid humanoid robot, also called "Parody", "Futura", "Robotrix", or the "Maria impersonator" (played by German actress Brigitte Helm), perhaps the most memorable humanoid robot ever to appear on film, is depicted in Fritz Lang's film *Metropolis*.

1941-42

Isaac Asimov formulates the Three Laws of Robotics, and in the process of doing so, coins the word "robotics".

1948

Norbert Wiener formulates the principles of cybernetics, the basis of practical robotics.

1961

The first digitally operated and programmable non-humanoid robot, the Unimate, is installed on a General Motors assembly line to lift hot pieces of metal from a die casting machine and stack them. It was created by George Devol and constructed by Unimation, the first robot manufacturing company.

1969

D.E. Whitney publishes his article "Resolved motion rate control of manipulators and human prosthesis".

1970

Miomir Vukobratović has proposed Zero Moment Point, a theoretical model to explain biped locomotion.

1972

Miomir Vukobratović and his associates at Mihajlo Pupin Institute build the first active anthropomorphic exoskeleton.

1973

In Waseda University, in Tokyo, Wabot-1 is built. It was able to communicate with a person in Japanese and to measure distances and directions to the objects using external receptors, artificial ears and eyes, and an artificial mouth.

1980

Marc Raibert established the MIT Leg Lab, which is dedicated to studying legged locomotion and building dynamic legged robots.

1983

Using MB Associates arms, "Greenman" was developed by Space and Naval Warfare Systems Center, San Diego. It had an exoskeletal master controller with kinematic equivalency and spatial correspondence of the torso, arms, and head. Its vision system consisted of two 525-line video cameras each having a 35-degree field of view and video camera eyepiece monitors mounted in an aviator's helmet.

1984

At Waseda University, the Wabot-2 is created, a musician humanoid robot able to communicate with a person, read a normal musical score with his eyes and play tunes of average difficulty on an electronic organ.

1985

Developed by Hitachi Ltd, WHL-11 is a biped robot capable of static walking on a flat surface at 13 seconds per step and it can also turn.

1985

WASUBOT is another musician robot from Waseda University. It performed a concerto with the NHK Symphony Orchestra at the opening ceremony of the International Science and Technology Exposition.

1986

Honda developed seven biped robots which were designated E0 (Experimental Model 0) through E6. E0 was in 1986, E1 – E3 were done between 1987 and 1991, and E4 - E6 were done between 1991 and 1993.

1989

Manny was a full-scale anthropomorphic robot with 42 degrees of freedom developed at Battelle's Pacific Northwest Laboratories in Richland, Washington, for the US Army's Dugway Proving Ground in Utah. It could not walk on its own but it could crawl, and had an artificial respiratory system to simulate breathing and sweating.

1990

Tad McGeer showed that a biped mechanical structure with knees could walk passively down a sloping surface.

1993

Honda developed P1 (Prototype Model 1) through P3, an evolution from E series, with upper limbs. Developed until 1997.

1995

Hadaly was developed in Waseda University to study human-robot communication and has three subsystems: a head-eye subsystem, a voice control system for listening and speaking in Japanese, and a motion-control subsystem to use the arms to point toward campus destinations.

1995

Wabian is a human-size biped walking robot from Waseda University.

1996

Saika, a light-weight, human-size and low-cost humanoid robot, was developed at Tokyo University. Saika has a two-DOF neck, dual five-DOF upper arms, a torso and a head. Several types of hands and forearms are under development also. Developed until 1998.

1997

Hadaly-2, developed at Waseda University, is a humanoid robot which realizes interactive communication with humans. It communicates not only informationally, but also physically.

2000

Honda creates its 11th bipedal humanoid robot, ASIMO.

2001

Sony unveils small humanoid entertainment robots, dubbed Sony Dream Robot (SDR). Renamed Qrio in 2003.

2001

Fujitsu realized its first commercial humanoid robot named HOAP-1. Its successors HOAP-2 and HOAP-3 were announced in 2003 and 2005, respectively. HOAP is designed for a broad range of applications for R&D of robot technologies.

2003

JOHNNIE, an autonomous biped walking robot built at the Technical University of Munich. The main objective was to realize an anthropomorphic walking machine with a human-like, dynamically stable gait

2003

Actroid, a robot with realistic silicone "skin" developed by Osaka University in conjunction with Kokoro Company Ltd.

2004

Persia, Iran's first humanoid robot, was developed using realistic simulation by researchers of Isfahan University of Technology in conjunction with ISTT.

2004

KHR-1, a programmable bipedal humanoid robot introduced in June 2004 by a Japanese company Kondo Kagaku.

2005

The PKD Android, a conversational humanoid robot made in the likeness of science fiction novelist Philip K Dick, was developed as a collaboration between Hanson Robotics, the FedEx Institute of Technology, and the University of Memphis.

2005

Wakamaru, a Japanese domestic robot made by Mitsubishi Heavy Industries, primarily intended to provide companionship to elderly and disabled people.

2007

TOPIO, a ping pong playing robot developed by TOSY Robotics JSC.

2008

KT-X, the first international humanoid robot developed as a collaboration between the five-time consecutive RoboCup champions, Team Osaka, and KumoTek Robotics.

2008

Nexi, the first mobile, dexterous and social robot, makes its public debut as one of *TIME* magazine's top inventions of the year. The robot was built through a collaboration between the MIT Media Lab Personal Robots Group, Xitome Design UMass Amherst and Meka robotics .

2009

HRP-4C, a Japanese domestic robot made by National Institute of Advanced Industrial Science and Technology, shows human characteristics in addition to bipedal walking.

2009

Turkey's first dynamically walking humanoid robot, SURALP, is developed by Sabanci University in conjunction with Tubitak.

2010

NASA and General Motors revealed Robonaut 2, a very advanced and humanoid robot. It is intended to do spacewalks for NASA.

2010

Students at the University of Tehran, Iran unveil the Surena II. It was unveiled by President Mahmoud Ahmadinejad.

2010

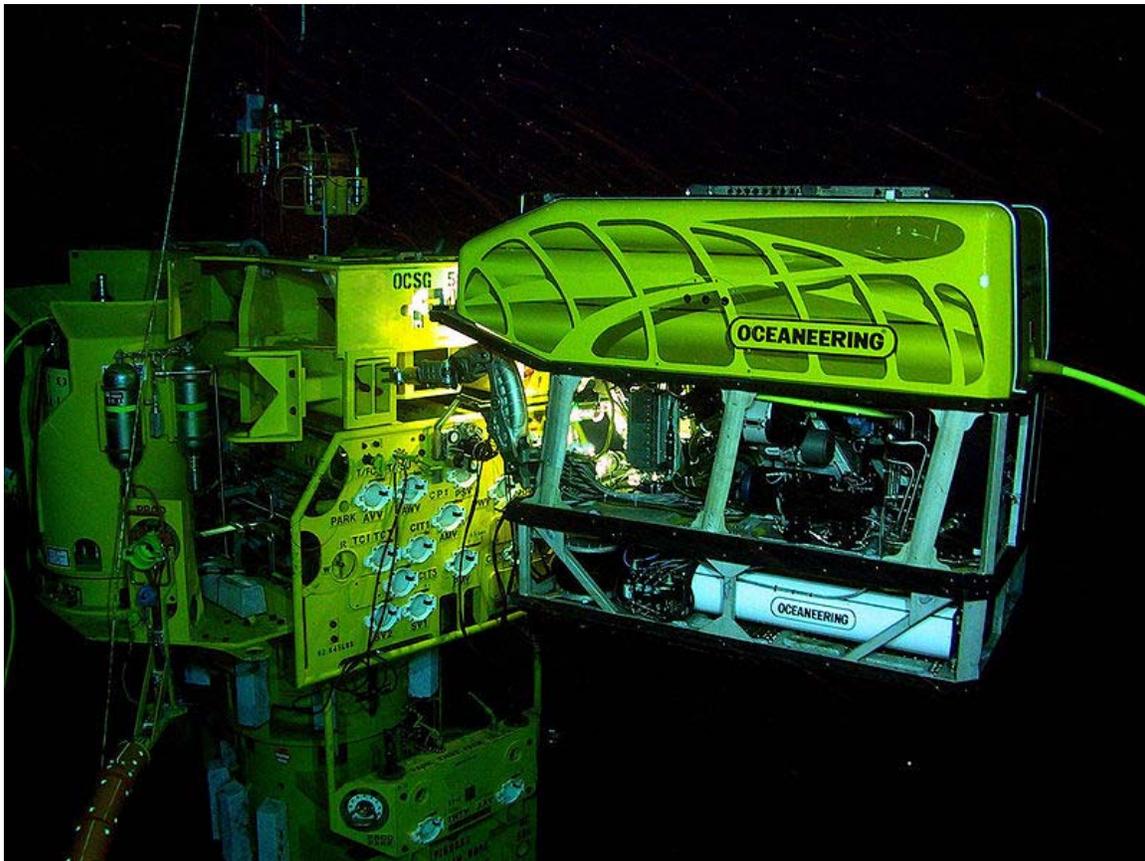
Researchers at Japan's National Institute of Advanced Industrial Science and Technology demonstrate their humanoid robot HRP-4C singing and dancing along with human dancers.

2010

in September the National Institute of Advanced Industrial Science and Technology also demonstrates the humanoid robot HRP-4. The HRP-4 resembles the HRP-4C in some regards but is called "athletic" and is not a gynoid.

Chapter- 9

Remotely Operated Underwater Vehicle



ROV at work in an underwater oil and gas field. The ROV is operating a subsea torque tool (wrench) on a valve on the subsea structure.

A **remotely operated vehicle (ROV)** is a tethered underwater robot. They are common in deepwater industries such as offshore hydrocarbon extraction. An ROV may sometimes be called a **remotely operated underwater vehicle** to distinguish it from remote control vehicles operating on land or in the air. ROVs are unoccupied, highly manoeuvrable and operated by a person aboard a vessel. They are linked to the ship by a

tether (sometimes referred to as an umbilical cable), a group of cables that carry electrical power, video and data signals back and forth between the operator and the vehicle. High power applications will often use hydraulics in addition to electrical cabling. Most ROVs are equipped with at least a video camera and lights. Additional equipment is commonly added to expand the vehicle's capabilities. These may include sonars, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration and temperature.

History

In the 1950s the Royal Navy used "Cutlet", a remotely operated submersible, to recover practice torpedoes.

The US Navy funded most of the early ROV technology development in the 1960s into what was then named a "Cable-Controlled Underwater Recovery Vehicle" (CURV). This created the capability to perform deep-sea rescue operation and recover objects from the ocean floor, such as a nuclear bomb lost in the Mediterranean Sea after the 1966 Palomares B-52 crash. Building on this technology base; the offshore oil & gas industry created the work class ROVs to assist in the development of offshore oil fields. More than a decade after they were first introduced, ROVs became essential in the 1980s when much of the new offshore development exceeded the reach of human divers. During the mid 1980s the marine ROV industry suffered from serious stagnation in technological development caused in part by a drop in the price of oil and a global economic recession. Since then, technological development in the ROV industry has accelerated and today ROVs perform numerous tasks in many fields. Their tasks range from simple inspection of subsea structures, pipeline and platforms to connecting pipelines and placing underwater manifolds. They are used extensively both in the initial construction of a sub-sea development and the subsequent repair and maintenance.



A Royal Navy ROV (*Cutlet*) first used in the 50s to retrieve practice torpedoes and mines

Submersible ROVs have been used to locate many historic shipwrecks, including that of the RMS *Titanic*, the *Bismarck*, USS *Yorktown*, and SS *Central America*. In some cases, such as the SS *Central America*, ROVs have been used to recover material from the sea floor and bring it to the surface.



ROV on its way to work

While the oil & gas industry uses the majority of ROVs; other applications include science, military and salvage. Science usage is discussed below, the military uses ROV for tasks such as mine clearing and inspection. Approximately a dozen times per year ROVs are used in marine salvage operations of downed planes and sunken ships.

Construction

Conventional ROVs are built with a large flotation pack on top of an aluminium chassis, to provide the necessary buoyancy. Syntactic foam is often used for the flotation. A tool sled may be fitted at the bottom of the system and can accommodate a variety of sensors. By placing the light components on the top and the heavy components on the bottom, the overall system has a large separation between the center of buoyancy and the center of gravity: this provides stability and the stiffness to do work underwater.

Electrical cables may be run inside oil-filled tubing to protect them from corrosion in seawater. Thrusters are usually in all three axes to provide full control. Cameras, lights and manipulators are on the front of the ROV or occasionally in the rear to help in maneuvering.

The majority of the work class ROVs are built as described above; however, this is not the only style in ROV building. Specifically, the smaller ROVs can have very different designs, each geared towards its own task.

Military ROV



AN/SLQ-48 Mine Neutralization Vehicle

In October 2008 the U.S. Navy began to replace its manned rescue systems, based on the Mystic DSRV and support craft, with a modular system, the SRDRS based on a tethered, unmanned ROV called a pressurized rescue module (PRM). This followed years of tests and exercises with submarines from the fleets of several nations.

The US Navy also uses an ROV called AN/SLQ-48 Mine Neutralisation Vehicle (MNV) for mine warfare. It can go 1000 yards away from the ship, and can reach 2000 feet deep. The mission packages available for the MNV are known as MP1, MP2, and MP3.

- The MP1 is a cable cutter to surface the moored mine for recovery exploitation or EOD detonation.
- The MP2 is a bomblet of 75 lb PBXN-103 high explosive for neutralising bottom/ground mines.
- The MP3 is a moored mine cable gripper and a float with the MP2 bomblet combination to neutralise moored mines underwater.

The charges are detonated by acoustic signal from the ship.

The ROVs are only on Avenger class mine countermeasures ships. There are 14 ships, operating mostly off the coast of Japan and California, and there are always four US minesweepers in the Persian Gulf: USS *Ardent* (MCM-12), USS *Dextrous* (MCM-13), USS *Scout* (MCM-8) and USS *Gladiator* (MCM-11).

Science ROVs

ROVs are also used extensively by the science community to study the ocean. A number of deep sea animals and plants have been discovered or studied in their natural environment through the use of ROVs: examples include the jellyfish Bumpy and the eel-like halosaurs. In the USA, cutting edge work is done at several public and private oceanographic institutions, including the Monterey Bay Aquarium Research Institute (MBARI), the Woods Hole Oceanographic Institution (WHOI) (with *Nereus*), and the University of Rhode Island / Institute for Exploration (URI/IFE). The picture to the right shows the behavior and microdistribution of krill under the ice of Antarctica.



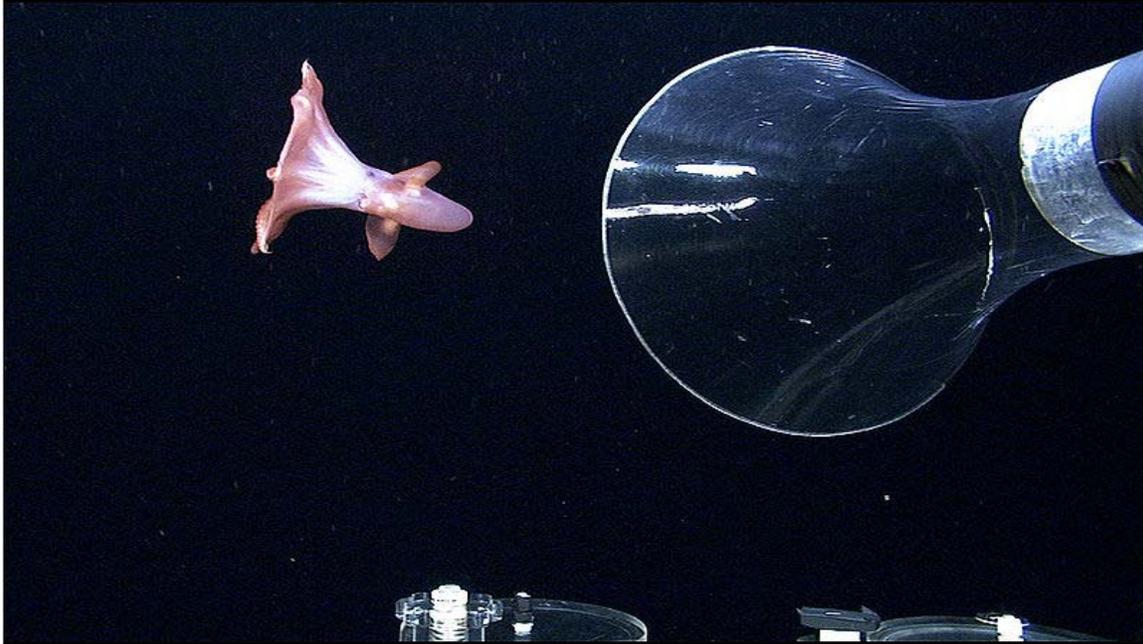
Image taken by a ROV under the ice of Antarctica. In the spring krill can scrape off the green lawn of ice algae from the underside of the pack ice in Antarctica. In this image most krill swim in an upside down position directly under the ice. Only one animal (in the middle) is hovering in the open water.

Science ROVs take many shapes and sizes. Since good video footage is a core component of most deep-sea scientific research, research ROVs tend to be outfitted with high-output lighting systems and broadcast quality cameras. Depending on the research being conducted, a science ROV will be equipped with various sampling devices and sensors. Many of these devices are one-of-a-kind, state-of-the-art experimental components that have been configured to work in the extreme environment of the deep ocean. Science ROVs also incorporate a good deal of technology that has been developed for the commercial ROV sector, such as hydraulic manipulators and highly accurate subsea navigation systems.



A science ROV being retrieved by an oceanographic research vessel.

While there are many interesting and unique science ROVs, there are a few larger high-end systems that are worth taking a look at. MBARI's *Tiburon* vehicle cost over \$6 million US dollars to develop and is used primarily for midwater and hydrothermal research on the West Coast of the US. WHOI's *Jason* system has made many significant contributions to deep-sea oceanographic research and continues to work all over the globe. URI/IFE's *Hercules* ROV is one of the first science ROVs to fully incorporate a hydraulic propulsion system and is uniquely outfitted to survey and excavate ancient and modern shipwrecks. The Canadian Scientific Submersible Facility *ROPOS* system is continually used by several leading ocean sciences institutions and universities for challenging tasks such as deep-sea vents recovery and exploration to the maintenance and deployment of ocean observatories.



A ROV's suction device about to capture a specimen of the deep sea octopus *Cirroteuthis muelleri*

Educational Outreach ROVs

The *SeaPerch* Remotely Operated Underwater Vehicle (ROV) educational program is an educational tool and kit that allows elementary, middle, and high-school students to construct a simple, remotely operated underwater vehicle, from polyvinyl chloride (PVC) pipe and other readily made materials. The *SeaPerch* program teaches students basic skills in ship and submarine design and encourages students to explore naval architecture and marine and ocean engineering concepts. *SeaPerch* is sponsored by the Office of Naval Research, as part of the National Naval Responsibility for Naval Engineering (NNRNE), and the program is managed by the Society of Naval Architects and Marine Engineers.

The Marine Advanced Technology Education (MATE) Center uses ROVs to teach middle school, high school, community college, and university students about ocean-related careers and help them improve their science, technology, engineering, and math skills. MATE's annual student ROV competition challenges student teams from all over the world to compete with ROVs that they design and build. The competition uses realistic ROV-based missions that simulate a high-performance workplace environment, focusing on a different theme that exposes students to many different aspects of marine-related technical skills and occupations. The ROV competition is organized by MATE and the Marine Technology Society's ROV Committee and funded by organizations such as the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Oceaneering, and many other organizations that recognize the value of highly trained students with technology skills such as ROV designing, engineering, and piloting. MATE was established with funding from the

National Science Foundation and is headquartered at Monterey Peninsula College in Monterey, California.

Classification

Submersible ROVs are normally classified into categories based on their size, weight, ability or power. Some common ratings are:

- Micro - typically Micro class ROVs are very small in size and weight. Today's Micro Class ROVs can weigh less than 3 kg. These ROVs are used as an alternative to a diver, specifically in places where a diver might not be able to physically enter such as a sewer, pipeline or small cavity.
- Mini - typically Mini Class ROVs weigh in around 15 kg. Mini Class ROVs are also used as a diver alternative. One person may be able to transport the complete ROV system out with them on a small boat, deploy it and complete the job without outside help. Occasionally both Micro and Mini classes are referred to as "eyeball" class to differentiate them from ROVs that may be able to perform intervention tasks.
- General - typically less than 5 HP (propulsion); occasionally small three finger manipulators grippers have been installed, such as on the very early RCV 225. These ROVs may be able to carry a sonar unit and are usually used on light survey applications. Typically the maximum working depth is less than 1,000 metres though one has been developed to go as deep as 7,000 m.
- Light Workclass - typically less than 50 hp (propulsion). These ROVs may be able to carry some manipulators. Their chassis may be made from polymers such as polyethylene rather than the conventional stainless steel or aluminium alloys. They typically have a maximum working depth less than 2000 m.
- Heavy Workclass - typically less than 220 hp (propulsion) with an ability to carry at least two manipulators. They have a working depth up to 3500 m.
- Trenching/Burial - typically more than 200 hp (propulsion) and not usually greater than 500 hp (while some do exceed that) with an ability to carry a cable laying sled and work at depths up to 6000 m in some cases.

Submersible ROVs may be "free swimming" where they operate neutrally buoyant on a tether from the launch ship or platform, or they may be "garaged" where they operate from a submersible "garage" or "tophat" on a tether attached to the heavy garage that is lowered from the ship or platform. Both techniques have their pros and cons; however very deep work is normally done with a garage.

Naming conventions

ROVs that are manufactured following a standardized design are commonly named by a brand name followed by a number indicating the order of manufacture. Examples would be *Sealion 1* or *Scorpio 17*. The design of a series of ROVs may have changed

significantly over the life of an ROV series, however an ROV pilot will often be familiar with the idiosyncrasies of a particular vehicle by name.

ROVs that are one-off or unique designs may be given a unique name similar to the style used for ships. ROVs are not normally referred to in the female gender as ships may be, but in the neutral gender.