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**Humanoid Robots**

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# Humanoid Robots

## **Abstract:**

To look at, it is a human, but from inside it is a machine. This is a humanoid robot. It is a machine that walks, talks, looks and thinks like a human being. Humanoid robots are on their way to take over the future.

In this paper I have tried to look into the technologies required in building the humanoid robot, what is the current scenario and what we can expect in the future. I have also talked about the possible hurdles that can be encountered in producing the humanoid and also the ill-effects the humanoid might have on humans.

## **Introduction:**

From time immemorial human beings have been dependant on machines and slaves. Slaves were made to do all kinds of tasks on behalf of their masters. When slavery was abolished man looked forward to machines. Machines are tools that are used by people to help them save time and energy. With advances in technology the machines have upgraded. Old machines have become obsolete, paving way for advanced machines. Machines have been able to achieve what humans had not even dreamt of earlier. With path-breaking advancements in electronics automation took over the machine world.

One such form of machine is the robot. A robot is an electro-mechanical machine, guided by computer or electronic programming, enabling it to perform specific tasks on its own. According to the Encyclopaedia Britannica a robot is “any automatically operated machine that replaces human effort”.

Humanoid robots are essentially robots with appearances resembling the human body. They consist of arms, legs, eyes, ears and other parts similar to the human body. Even the anatomy is similar – we, humans have a central processing unit in the brain, a battery to supply life in the heart, and a nervous system to connect the different parts inside our body. The nerves sense stimuli and transmit the data to the brain where data gets processed and the reaction is again transmitted back through the nerves. A robot also consists of a bundle of wires working as the nerves.

Now why would we need a humanoid robot? The list could be endless. Every human being would want to use a robot for different purposes. One could use a robot to wake him up in the morning, serve his coffee, shave his beard, wash the car, vacuum the carpet, read out the news and even work as a night guard. A child can have a pet robo-friend, who not only would play with the kid but also look after her. Humanoid robots will have massive roles to play in military also. Humanoid robots will also be used to perform critical surgeries. The uses can be endless. But the question is when all these can be converted into reality.

## Technologies to be used:

The technologies required to successfully manufacture a humanoid robot that will comply with requirements of the future are difficult to attain but not impossible. On the inside the 'brain' of the humanoid must consist of microchips that should be powerful enough to perform all the complex functions and process information a number of times faster than what it is capable to do in the present. The chips should also be reliable and there should be substitute chips available if the main one ceases to function because of some cause.

The whole skeleton should consist of a very strong yet light material. It should be strong because the internal components would be very expensive as well as delicate. We cannot afford to cause much damage to the internal 'organs' of the humanoid as there won't be not much difference between you, me and him. The structure should be also light as he would have to carry his weight to walk, run and jump. Nowadays the humanoid robots are very heavy and that is why they are not at all swift. But to realise our dream the humanoids should weigh ideally between 70 and 90 kgs, just like the normal human being. It can use a material like titanium for its basic framework.

One of the main parts of the human body is the heart. It is the supplier of life for the man. In a humanoid you can compare it with the battery. The battery is what that will drive the components including the chips, sensors, actuators, etc, as well as provide power for the movements of the limbs, arms and other parts.

Currently mostly lead-acid batteries are used for robots but potential power sources can be:-

- Pneumatic (compressed gases)
- Hydraulics (compressed liquids)
- Organic Garbage
- Nuclear Fission reactors
- Radioactive Sources

The battery should be rechargeable, preferably by solar power. Its capacity should be huge, much more than currently feasible. Unless this is sorted out there will not be much use of the humanoid robot. It won't be feasible if the robot has to go and charge the battery at small intervals. The Humanoid robot will have the sensors that will guide him to a power source automatically when the battery level comes down below a certain limit. The battery would also get automatically recharged during daytime by sunlight. This way it would be environment friendly also. But for that high capacity solar cells are required. But that won't be much a problem as researchers are working hard to get the most of the free energy provided by Sun.

Most electronic equipments are damaged by water. But our robots should be water resistant. This can be achieved by making the skin impermeable to water.

The humanoid robot's outer protective cover is his skin. The skin will contain a number of sensors that will collect data and transmit to the central processing unit. Currently robotic hands receive far less tactile information than human hands. But recent developments have created a sensor array that mimics the mechanical properties and touch receptors of human fingertips. But to match the reception of a human skin the current technology has to be spread out for the entire skin of the humanoid robot. This is a challenging task as skin spreads all over the body and the whole system of sensors will take up a huge space, considering the dimensions of the humanoid robot. In the latest technology electrodes are mounted on the surface of the rigid core (bones of the humanoid)

and are connected to an impedance – measuring device within the core. When the artificial skin touches an object the fluid path around the electrodes is deformed, producing impedance changes from the forces received from the object. This function will be important to adjust the robotic grip on objects held by the robot arm. One prosthetic hand made in 2009, called Smart hand, functions like a real hand which allows patients to write, type or play piano and perform other fine movements. Modification of this arm can also be used by the humanoid robot effectively.



Fig. An artificial hand holding a light bulb

Source: [http://en.wikipedia.org/wiki/humanoid\\_robot](http://en.wikipedia.org/wiki/humanoid_robot)

Muscles are the tissues in animals that are used produce force and motion. Muscles are responsible for the locomotion of the organism as well as movement of the internal organs. Currently the muscles used in a humanoid robot move hundred times slower than our muscles. But Massachusetts Institute of Technology researchers are in the process of inventing robotic muscles that would work one thousand times faster than the human muscle, that too without requiring any extra energy. Conjugated polymers will be used as the base for these muscles. The muscles can run on hydrogen to make the movements soundless. A team of researchers from the University of Texas have also made a robotic muscle that is being considered as a major leap forward. They have got an entirely new material comprised of ribbons of tangled nanotubes, which can expand its width by 220% when voltage is applied to it and then return back to its original shape in just milliseconds when the voltage is removed. This material can withstand extreme temperatures ranging from -196 degree Centigrade to 1538 degree centigrade and is extremely strong and stiff.

Ultimately what will matter is the 'brain' of the humanoid. The brain here like that of the human will also have different parts. One part will take care of the information it receives from the outside world. This part has will have face recognition software, voice recognition software and also movement interpretation software. Apart from that this part would also tell about the temperature, humidity, pollution of the surrounding.

Artificial Intelligence: The human being is incomplete without intelligence. To make a humanoid robot live up to its expectation it should have a very strong Artificial Intelligence unit. This technology is still in its childhood stage. But it has to grow for the humanoid robots to exist with humans. A.I should reach a level where the humanoid can itself differentiate between what is good for it and what is not. It should record incidents and learn from them. The same way a human being adapts to different situations the humanoid will also be able to adapt. This development of A.I is the most important aspect for the humanoids to become feasible. The technology is here but needs vast enhancements.

For creating artificial intelligence the matter has been broken down into a number of specific sub-problems:

- Deduction, reasoning, problem solving: –  
Early algorithms imitated the step-by-step reasoning human beings used to solve puzzles or make logical decisions. Later highly successful methods were developed to deal with incomplete or uncertain information. Concepts of probability and economics were borrowed to form the algorithm. These algorithms require huge computational resources. The computer time required becomes very high when the problem goes beyond a certain size. This is the main drawback of employing Artificial Intelligence. So, to employ Artificial Intelligence for humanoid robots the computing power has to increase substantially. Human beings deal with complex problems and to make the humanoid be able to tackle those is a challenge. Human beings solve a majority of their problems using fast, intuitive judgements rather than conscious step-by-step deduction. For example, when people cross the road they not always stop and look at the vehicle coming and then calculate the estimated time for it to reach them. Artificial intelligence have made some progress at imitating this kind of 'sub-symbolic' problem solving : embodied agent approaches emphasize the importance of sensorimotor skills to higher reasoning; natural net research attempts to simulate the structures inside human and animal brains that give rise to this skill. Also researchers can study the growth of a human brain from birth to find answers to the skill development in humans.
- Knowledge Representation:-  
To solve the problems a humanoid will require extensive knowledge about the world. Among the different things Artificial Intelligence need to represent are – objects, properties, categories and relation between objects, situations, events, states and time, causes and effect and many other domains. Many of the things people know come from working assumptions. The number of small facts the average human being knows is astronomical. Thus for the humanoid to build a knowledge base of commonsense knowledge enormous amounts of laborious ontological reasoning is required. To have the humanoid robot understand enough concepts to be able to learn from reading from sources like the internet is a major challenge.
- Planning:-  
Intelligent agents must be able to set goals and achieve them. The humanoid robot will also have to plan for the future. They must have a representation of the world in its current scenario and predict the future and plan accordingly. This is to be done so that the humanoid can change its plan of action and develop new ones. In addition to that, he has to evaluate the options available to him related to a problem and maximize the utility from the options. In classical programming a machine assumes about the consequences of its

action, which remains a constant. But in real world the parameters change and thus the humanoid will also have to check the consequences of its action. How the world has been affected by the humanoid's action must act as a feedback him to change his future course, of action.

- **Learning:-**  
Machine Learning has been a central aspect of Artificial Intelligence. Learning is the ability to find patterns in a stream of input. The humanoid must be able to learn on itself from the data acquired by him.
- **Natural Language Processing: -**  
This gives the humanoid to be able to read and understand the language humans speak. The challenge is to understand voice and differentiate the words and understand after that.
- **Motion and manipulation:**  
Intelligence is required for humanoid robots to be able to handle tasks as object manipulation and navigation. Also there are other problems like knowing where you are (localization), knowing what all things are around you (mapping) and figuring how to get to a place (motion planning)
- **Perception:**  
Perception is the ability to interpret data from the sensors like cameras, microphone, sonar and other input devices to create an image of the environment of the humanoid robot. Computer vision is the ability to analyze visual input. Other problems that come into perception's domain are speech recognition, voice recognition, and facial recognition and object identification.
- **Social intelligence:**  
Social intelligence for a humanoid robot deals with emotion and social skills. The humanoid robot needs to be able to predict the actions of others by analyzing current situations. He also has to understand other people's motives and emotional states.
- **General Intelligence:**  
Researchers hope that eventually their work will be incorporated into a machine with general intelligence. General intelligence is strong artificial intelligence. It is a combination of all the skills of artificial intelligence. Ultimately the humanoid robot will exceed human abilities in most of these skills. Artificial brain or artificial consciousness may be required for this.

In 2008, University of Reading Scientists developed a robot controlled by a biological brain. It was formed from cultured neurons. This robot is a first step for explaining how memories manifest themselves in the brain and how the brain stores specific data. The brain here consists of a collection of neurons collected on a multi electrode array. It contains about 60 electrodes that pick up electrical signals generated by the cells. This is then used to direct the movement of the robot. Research is going on to check whether the robot can recognize a particular environment it has previously visited. The brain is not connected to any computers. This model of the robot brain can also be used with a computer to be the basic model for the brain of the humanoid robot. Along with this it has to contain all the other technologies required.

The brain of the humanoid robot would not be limited to only the skull, it has to be spread all over. The brain will take up the most part of the body of the robot as it is the main part.

For the humanoid robot to be operational, Robot Operating System can be used. It was originally developed in 2007 but research is needed on this. A Robot Operating System package application includes:-

- Perception
- Object Identification
- Segmentation and Recognition
- Face Recognition
- Gesture Recognition
- Motion Tracking
- Ego-motion
- Motion understanding
- Structure from motion(SFM)
- Stereopsis
- Mobile robotics
- Planning
- Grasping

RFID can become an integral part of the humanoids. It can be used to locate the robots and also the robots can use them to accurately pin point other objects. RFID is radio frequency identification is currently used in a lot of places for identification and warehousing. In this technology communication takes place via electromagnetic waves involving an exchange of data between a terminal and an object. RFID involves a tag and a reader. It is used to keep track of a particular object. RFID tags not always require power to become active. The RFID tag and even a reader can be incorporated into the humanoid robot's body so that it can be identified and tracked easily. Also the humanoid itself would be able to find out other humanoids and keep a track of other things that has got RFID tags in them.

3D Face recognition: 3 D sensors are used to capture information about the shape of a face. The information gathered is then used to identify distinct features on the face. It can identify the contour of the eye sockets, nose and chin to get a more accurate image of the person. The face detected will be saved in the memory of the humanoid robot and can be used for future reference and to extract details about the person for future interactions.

Voice Recognition: Voice recognition technology will be used to capture the voice of the individual the robot would be interacting with and from there it would be able to differentiate between different persons on the basis of their voices.

Finger Print: The humanoid will have a finger print detector in his hand which will capture the image while the human is shaking hands with the robot. This along with Face recognition and voice recognition would enable the humanoid robot to identify each person distinctly.

Sonar: Sonar uses a transmitter and receiver to detect another object. This technology can be used in the humanoid robot to navigate, detect other objects or even communicate.

In addition the Humanoid robot will have a built-in GPS system so that it can exactly track its location and let others track his position on the planet. GPS or Global Positioning System is a space based global navigation satellite system that gives the location of an object by tracking it with the help of multiple satellites.

Automatic software updates would keep the humanoid more efficient. Many problems can be addressed to by the use of internet availability inside the humanoid. The humanoid will have a wi-fi

or wi-max receiver inside its body and will also have a router. The humanoid will be able to update its software from the internet and even provide internet connection to devices near it by being a router.

**Actuators:** An actuator is a mechanical device for moving or controlling a mechanism or system. It converts energy into motion. Generally electric current or hydraulic fluid pressure is converted into movement of the different parts of the humanoid robot. Actuators are the motors responsible for the motion of the robots. Actuators act as the muscles and joints of the human body. The flexibility of joints in a human is limited. But a robot can have more freedom in its movements. Humanoid robots mainly use rotary actuators. The actuators mainly used in humanoid robots are:

- Electric
- Pneumatic
- Hydraulic
- Piezoelectric
- Ultrasonic

## **CURRENT HUMANOID ROBOTS:**

- **NAO**  
It is an autonomous programmable humanoid robot developed by the French company, Aldebaran robotics. Nao was primarily built for companionship. This robot was used in the robocup, which is an international robotics competition. The robot is very small ( only 58 cms ) and weighs just 4.3 kgs. It has got internet connectivity and can play soccer.



Fig. Nao

Source:[http://en.wikipedia.org/wiki/humanoid\\_robot](http://en.wikipedia.org/wiki/humanoid_robot)

- **ENON**  
Enon is a personal assistant robot which is self guiding but with limited speech recognition and synthesis. It can shake hands and pick up weights upto 500 gms in its arms. Enon is also used for patrolling, guidance and escorting. Enon was first offered for sale in September 2005 by Fujitsu Corporation in Japan and costs about US\$ 60,000.
- **ASIMO**  
Asimo is the humanoid robot created by Honda. It weighs only 54 kilograms and looks like an astronaut with a backpack. It has the ability to walk or run upto a speed of 6 km/hr. The height of Asimo is 4 feet 3 inches and is the most human-like robot Honda has made so far. The cost of manufacturing each Asimo robot is \$ 1 Million. The battery of Asimo gets discharged in about 1 hour of walking. The robot can be operated from a workstation and also by remote control. Asimo has the ability to detect the movement of multiple objects, assessing distance and direction. It has the ability to follow a person or even greet a person when approached. Asimo can also detect hand movements of humans and thus



can react to when a person is offering for a handshake. Not only voice commands but hand pointing can also direct Asimo. Asimo also has the ability to distinguish sound from noise and can recognise human faces that are registered in his memory. It has also got internet connectivity and thus can give news updates and weather information. The latest version of Asimo can perform uninterrupted services to office guests. Asimo has basically got most of the functions our humanoid robot of the future requires. The only thing is that the technology has to make advancements and the cost to reduce for the user to use the robot.



Fig. Asimo

source: [world.honda.com](http://world.honda.com)

- HRP -2  
It is a humanoid robot that can walk on uneven surfaces, narrow paths at a speed equal to two-thirds of the speed of a human being.
- TOPIO  
Topio is a bipedal humanoid robot which was designed to play table tennis against a human being. It has been developed by the Vietnamese firm TOSY. Its weight is 120 kgs and height about 1.88 meters. The robot can recognize fast moving objects and has fast and accurate movement control. It can also walk in a balanced manner.



Fig. Topio

Source: <http://en.wikipedia.org/wiki/topio>

- Lara  
Lara is a humanoid robot that has got brought innovation in metal alloy muscle and foot technology. There are 38 artificial muscles, which enables Lara to have six degrees of freedom in each leg and three degrees in each arm. The metal alloy strands instantly contract when heated by electric current.

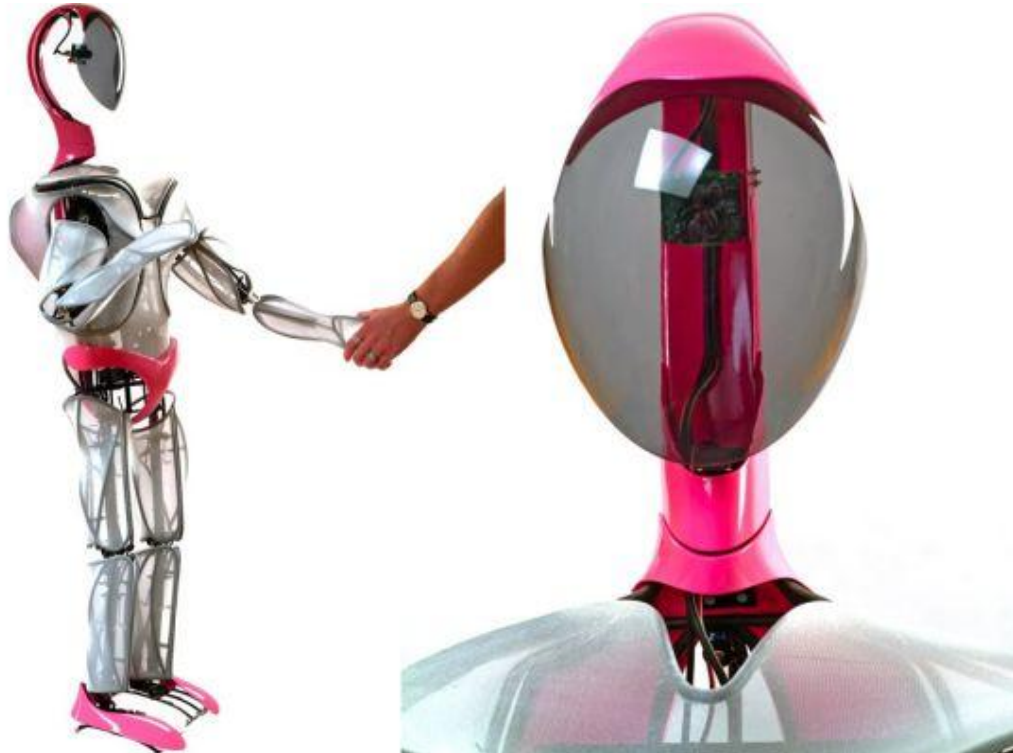


Fig: Humanoid robot Lara

Source: [www.lara-robot.de](http://www.lara-robot.de)

To create the desired humanoid robot in the next 5 decades robotic research should be done in a collaborative way. Technology advancements made by one laboratory must be available to others.

It is not possible for one company to research and develop all the technologies required for our humanoid robot. There should be one organization responsible for the development of the humanoid robot. Different companies and research laboratories should come under that particular organization and work on the technologies. One might be good in one thing but requires help in the other. Collaboration is the answer to this problem.

Humanoid robots can be sent to places where a risk factor is associated with humans – from the core of the earth to the outer space. Humanoids can be sent to planets like Mars, Venus to check out the environment there and carry out tests and experiments.

Already there are robots that are used in industries to work in complex processes. Humanoids can be used to do jobs where perfection is a key. Also they can be sent to work in places where it is demanding for the normal human being to survive, like in dangerous mines and underwater.

One negative impact of the humanoid can be its use in warfare. With sufficient outer protection, a walking humanoid with weapons can wreck havoc. It would be difficult to encounter an army of robots whom it is difficult if not impossible to kill.

Humanoid Robots can be used as companions also. A child as well as a grown up can find a friend in a humanoid. They can be even taken care of by the robots. The humanoid robot can look after and chat with a kid or an elderly at the same time. It can be an educational, playing and interactive partner for a young kid. The kid would be able to learn and play at the same time even when the parents are not nearby to look after.

## **Economic Potential of the Idea:**

The humanoid robot is a thing for the future. Man, being dependant on machines will definitely spend money to own a humanoid robot. A machine that resembles a human being will be accepted by the majority of the targeted consumers.

The robots have to be built in masses that would reduce the cost of production. Initially the prices are expected to be high but as competition in the humanoid robot industry increases the manufacturers are bound to slash down prices. This industry has the potential to take over the world by storm when a good quality robot is manufactured. From then on advancements in technology that are not even thought of today will play a key part in differentiating the products of different companies. Humanoid robots can be used by a number of sectors, including the army, healthcare, police and the common people also.

The army can use the robots to boost up their defence as well as attacking options. The humanoids will master the art of choosing and destroying the targets and can be even customized for specific actions during warfare. So it would be a wise idea for the manufacturers to sell robot armies to countries.

Robots in a doctor's uniform will be handy in performing critical operations where accuracy is very important. Hospitals can 'recruit' humanoid robot surgeons to perform these operations. Cash can be generated by tying up with healthcare institutes.

The police system can use humanoid robots to maintain law and order in the cities. The humanoid robots would be intelligent enough to differentiate between the good and evil roaming in the city streets. They would also come in handy to help the common public by giving them guidance and assisting them.

Just like today's amusement parks companies can open up robotic parks where people can interact and watch these humanoid robots performing various activities. You can even imagine a robotic city where the inhabitants will be the humanoids and humans would pay entry fees to be a part of the technological marvel. A company manufacturing humanoid robots can themselves have such a kind of tech-park or even sell the robots to other organizations who would build up the amusement parks.

Apart from this the common man also has an incentive to acquire a humanoid robot. The robot can be used as a helping hand for the daily indoor activities in a household. So companies can also directly sell the robots to common people. Moreover by paying a little more than the general price people can order customized robots which would have faces as desired by the customer. Also there can be add-on features that would cater to specific needs of the consumers. An intelligent humanoid robot can even assist human beings in taking decisions in their lives. The robot will also be a source of wi-fi internet connectivity and that will come in handy to the users.

Basically the humanoid robot will make a lot of current applications obsolete when it comes to proper existence. The marketing of these robots have to be done in a proper way so that people will believe in the product. Demonstrations and stage shows, along with advertising in the digital media will also play an important role in attracting customers.

## **Why this dream might end up not being a reality ...**

The cost associated with building a humanoid would be massive initially. But with mass production the prices are bound to go down drastically. It has to cross the initial hurdle, where it might be a good idea to sell the robots to the military departments of different countries, as well as to the rich people of the planet. With increased popularity and start in mass production the general public would become able to afford the humanoids for themselves. Also competition in the robotic industry might lead to lower base prices on the humanoid robots and prices would depend on special features that different companies would be able to provide.

Artificial intelligence is a part of science and its consequences depend on how one would want to use it. The movie trilogy 'Matrix' might be a work of fiction but it also warns us in advance from the perils of humanoid robots, in particular, with Artificial Intelligence. An intelligent human can convert atomic power to a devastating bomb. He can use technology to invent weapons of mass destruction; he can wedge wars to win land. Then why cannot an intelligent robot? This is what has been depicted in the movie 'Matrix', where the robots became so technically advanced and they became artificially so much intelligent that ultimately a war ensued between the human kind and the machine kind.

The humanoid robots should possess Artificial intelligence but there must be a regulation on their level of intelligence. We cannot endanger our own species to cater to a want, not a need. Science is something that promises many rewards on one hand and demolition on the other. Researchers want artificial intelligence to attain a level which would be at par to, if not higher than the human intelligence. But to achieve this collaborative thinking and research has to be done by the best brains of the world. There should be a regulatory body that would keep an eye on the level of intelligence of the humanoid robots so that they will not be able to go out of control and override human control.

## Conclusion

Many people might debate over the feasibility of humanoid robots the way we want it to be, but it is not improbable or impossible. Technology advancements in every sector are taking place in a rapid phase. Still the biggest hurdle will be to generate artificial intelligence that will compete with human intelligence. The concept of aeroplane flying in the air was not only a dream but considered to be even beyond that centuries back. But now aeroplane is nothing amazing for even a 5 year old child. Moon was just an object to look at in the sky previously, but now people are buying property on moon. Humanoid robots were also not conceived of decades back but now that the basic form has arrived, our potential non-life companion is not far behind. And it is a matter of time when humans and humanoids will walk on this planet side by side.

## References:

- Humanoid robot HRP – 2  
By Kenji Kaneko, Fumio Kanehiro, Shuuji Kajita, Hirohisa Hirukawa, Toshikazu Kawasaki, Masaru Hirata, Kazuhiko Akachi and Takakatsu Isozumi
- Cerberus the Humanoid robot: Part 1 – Design  
By Mehmet Ismet Can Dede, Salim Nasser, Shusheng Ye and Sabri Tosunoglu
- Design of an autonomous humanoid robot  
By Gordon Wyeth, Damien Kee, Mark Wagstaff, Nathaniel Brewer, Jared Stirzaker, Timothy Cartwright, BartekBebel
- Links:
  - <http://en.wikipedia.org/wiki/Actuator>
  - [http://en.wikipedia.org/wiki/Mobile\\_Robotics](http://en.wikipedia.org/wiki/Mobile_Robotics)
  - [http://en.wikipedia.org/wiki/Humanoid\\_robot](http://en.wikipedia.org/wiki/Humanoid_robot)
  - [http://useactor.com/what\\_is\\_an\\_actuator.html](http://useactor.com/what_is_an_actuator.html)
  - <http://www.sciencedaily.com/releases/2008/08/080813175509.htm>
  - <http://www.zdnet.com/blog/emergingtech/exclusive-a-robot-with-a-biological-brain/1009>
  - [http://ieeexplore.ieee.org/xpl/freeabs\\_all.jsp?arnumber=1232659](http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1232659)
  - [http://en.wikipedia.org/wiki/Radio-frequency\\_identification](http://en.wikipedia.org/wiki/Radio-frequency_identification)
  - [http://en.wikipedia.org/wiki/Artificial\\_intelligence](http://en.wikipedia.org/wiki/Artificial_intelligence)
  - <http://en.wikipedia.org/wiki/Sonar>
  - [http://en.wikipedia.org/wiki/Future\\_of\\_robotics](http://en.wikipedia.org/wiki/Future_of_robotics)
  - <http://www.crazyengineers.com/forum/ce-infocus/18038-new-material-could-make-robot-muscles-better-faster-stronger.html>
  - <http://www.newscientist.com/article/mg20427305.600-hydrogen-muscle-silences-the-domestic-robot.html>
  - <http://www.azom.com/news.asp?newsID=4258>
  - <http://www.media.mit.edu/research/groups/biomechatronics>
  - <http://en.wikipedia.org/wiki/Robot>
  - [http://en.wikipedia.org/wiki/Autonomous\\_robot](http://en.wikipedia.org/wiki/Autonomous_robot)
  - <http://en.wikipedia.org/wiki/Ros>
  - <http://en.wikipedia.org/wiki/Robotics>
  - <http://en.wikipedia.org/wiki/Nao>
  - [http://en.wikipedia.org/wiki/Global\\_positioning\\_system](http://en.wikipedia.org/wiki/Global_positioning_system)

- [http://en.wikipedia.org/wiki/Facial\\_recognition\\_system](http://en.wikipedia.org/wiki/Facial_recognition_system)
- [https://inlportal.inl.gov/portal/server.pt/community/ethical\\_considerations/543](https://inlportal.inl.gov/portal/server.pt/community/ethical_considerations/543)
- <http://www.lara-robot.de/>
- <http://www.thedesignblog.org/entry/beauty-with-brains-the-lara-humanoid-robot/>
- <http://en.wikipedia.org/wiki/Asimo>
- <http://world.honda.com/ASIMO/>
- <http://en.wikipedia.org/wiki/Topio>