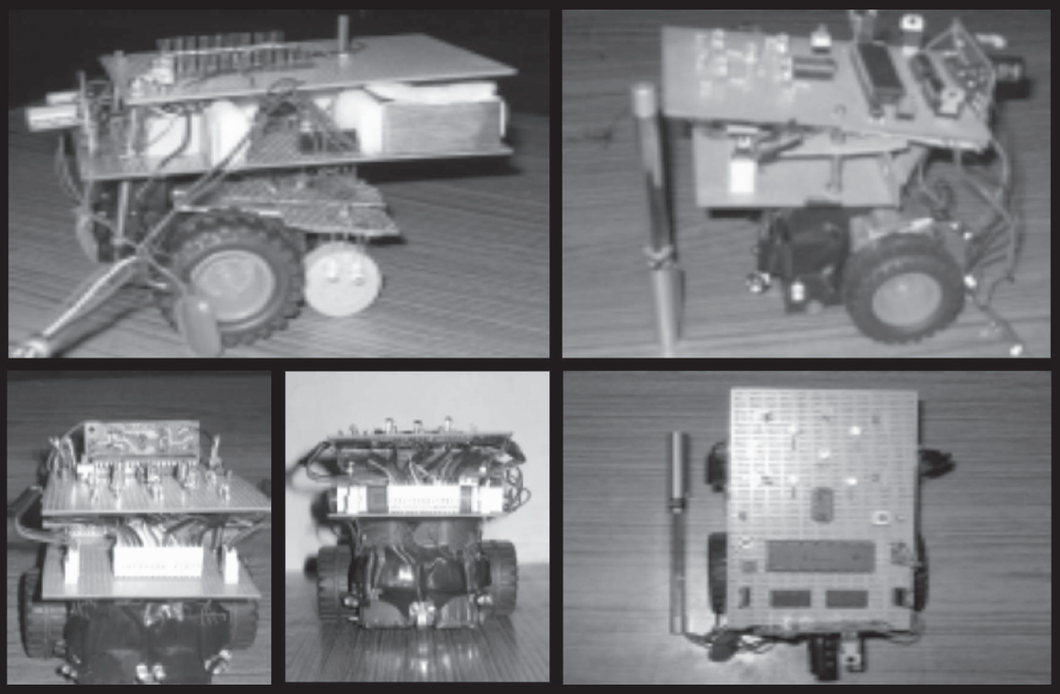
JANANI GOPALAKRISHNAN VIKRAM

Janani Gopalakrishnan Vikram has always been passionate about writing, especially on technology. A freelance writer, columnist, editor and editorial consultant, she writes on a variety of subjects ranging from science to philosophy, including business, cuisine, and life! Based in Bangalore, Janani contributes to fifteen publications across India. She is a regular contributor to the magazines of the EFY Group—BenefIT, i.t. Magazine and Linux For You, and other magazines like Tarla Dalal's Cooking and More, Windows & Aisles (Paramount Airways' in-flight magazine) and Eves Touch. She writes for portals such as indogram.com, sulekha.com and indusladies.com.

Janani won The PoleStar Award for the 'Best Feature in IT Journalism' for 2006 for her article, 'Those magnificent people and their amazing robots!', which appeared in i.t. Magazine.



THOSE MAGNIFICENT PEOPLE AND THEIR AMAZING ROBOTS!

They may not get the attention they merit, but robotics enthusiasts in our country are working on a number of amazing projects. And in spite of struggling to acquire components and sponsorships, they have shown that robotics in India is alive and kicking, and is not just restricted to a few elite organisations.

Much has been said about famous robots like Sony's AIBO, Honda's ASIMO and other humanoid robots. On the less glamorous front of industrial robotics, we have heard of SCARA. Closer home, IIT-Mumbai's Natraj has also attracted some attention. Information about these is easily available, but what about the work of lesser-known robotics enthusiasts, especially among Indian students. We reached out to them through Robotics India (http://nod.phpwebhosting.com/~robotics// index.php)—an online robotics destination, run by Vikas Patial, who is obviously an enthusiast himself—and came across several projects, involving hundreds of students. What follows is a brief description of some of these amazing projects.

Will Madan's robot help around the house?

Madan Kumar is a student of electronics engineering at Sri Venkateswara College of Engineering, Chennai. He started off making robots for contests, and his first robot was a Micromouse bot. Micromouse is a famous robotics contest, which is held in almost every tech fest. The participant robots or micromice need to be capable of navigating a maze, about which nothing is known in advance.

The latest project Madan is working on is an automatic navigator that will go to a prescribed location in a house. The project is in its first stage of development, and Madan is trying to make it move to a particular position in the house after overcoming every obstacle placed in its path. "I just have to give it the coordinates to go to, using a keyboard, and leave it free," he says.

And what does he aim to do with this automatic navigator? "Well, I am planning to make a robot that does all household work! So if the robot is let around the house once, it will divide the whole house into co-ordinates and store it in its memory, along with a note of the location of various objects and their coordinates.

Then when it is asked to, it will process your voice command, go to the location of the object in that particular co-ordinate of the house and pick it up," he says, making it all sound wonderfully logical.

A thorough robotics enthusiast, Madan maintains a website (http://invobot.tk) where he shares information about various aspects of designing and building robots.

Bharat's four-feet-tall wonder

Bharat Narahari (http://d.1asphost.com/bharatn/), a student of K J Somaiya IOE & IT, Sion, Mumbai, is part of a group of six students involved in a college-funded initiative to develop an autonomous robot for their final year project. The robot is 1.2 m (4 ft) tall, 0.6 m (2 ft) wide, and weighs approximately 35 kg.

The main features of the robot include autonomous behaviour using ultrasonic sensors, voice recognition, speech synthesis, Bluetooth-based teleoperation, RF control, motion detection, wireless control of home appliances using voice, SMS, Internet, radio waves, inclusion of a geographical positioning system (GPS) and a temperature sensor.

"Imagine that you are getting late for work and forget to switch off the lights and fans in your house before leaving. You remember this only after reaching your office and know there is no one at home. Not to worry. A single SMS to our robot will solve the problem—just send a command 'ALL OFF' and that is it! Instead of an SMS, you can also use Bluetooth or Internet communication to control our robot," says Bharat. And there's more!

"You can log on to the Net to see what your robot is seeing. This feature is called teleoperation, with which you can even control the robot. The robot can then be used in museums to guide people. The operator can sit at a base station and control the robot, and can also communicate wirelessly with the visitors as our robot provides the functionality of sound and voice integration. The robot is a surveillance system in itself. Give it the task of protecting precious diamonds at a jewellery store, and it will do it easily.

If anybody tries to pick up the protecte object, the robot will immediately sense it, and convey a signal to the owner by sounding an alarm or by sending an SMS. At the same time, it will also start recording the scene and take photos. These will be immediately uploaded and sent via e-mail to the owner," Bharat adds.

"On the lighter side, it can be used for entertainment because of its ability to speak and respond to voice. Our robot can be controlled with a remote control, and that by itself can be exciting. We can also extract the current temperature of the place where the robot is standing and this can be sent to a person wirelessly through an SMS. It can also find out the current latitude and longitude, overcome obstacles and move to a specified place, and do many other things," explains Bharat with justifiable pride.

Robo-doc Venki

Dr Venkatesh, a resident of Bangalore, believes in the 'catch them young' philosophy. A technology enthusiast, the doctor-cum social worker has been mentoring electronics and robotics projects for more than 30 years now. "I started the Bangalore Robotics group (http://groups.yahoo.com /group/bangalorerobotics/) in the year 2000, with the conviction that robotics, as a technical hobby, will trigger and ensure overall development of scientific reasoning, knowledge and skill. Robotics involves a lot of common sense and creativity along with skills in physics, electronics, mechanical, electrical and computer/information sciences. All these culminate in a robotic project that the students will be proud of," he says.

"My focus is on the numerous technical fests and events in India. Preparing for a competition has several benefits: the events are time-bound, allow innovations, are clear in their requirements, and are highly educative.

Robot rallies

There are several fests and contests that exhibit and test the prowess of robots (and their makers). Some of the popular ones include:

- Micromouse contests, which are held as part of almost every tech fest.
- RoboCup (http://www.robocup.org/), an International soccer tournament played by robots.
- BattleBots (http://www.battlebots.com/), considered to be the ultimate in robot sports.
- Robocon (http://www.roboconindia.com/), an annual contest conducted by the Asia Pacific Broadcasters Union that tests the skills of robotics enthusiasts with challenging themes every year. The theme for Robocon 2006 is to simulate the construction of the Malaysian PETRONAS twin towers and its surroundings, by a team of robots, using polystyrene builder blocks.

The spirit of competition ensures hard work, enhances knowledge, and develops presentation skills and depth of knowledge. This may not be a factor addressed or catered to by their colleges," says 'Doc Venki', as he is fondly called. "Bangalore Robotics is like a gurukula for school and college students interested in robotics. We do most of the work clustered together on the floor!" Dr Venkatesh also runs Docel Radio Research Inc, a Bangalore-based R&D house focusing on wireless technologies.

"As a social worker, my interests lie with human beings and society. It is this passion that makes me encourage and guide projects that help people. The era of industrial robots has blended with the domestic, due to saturation of technology and usage. But the overflow hasn't caught the fancy of people as yet. I try to talk my students into addressing the immediate need for public utility robots for the maximum benefit of society. You will see a few

talking robots designed by us, in parks and public places interacting with people with several messages like 'Do not litter', 'Smoking kills', 'May I help you?', 'Please keep off the grass', and so on," he says.

One of the most interesting projects mentioned by Dr Venkatesh is 'Helping Hand—The Talking Robotic Chair for Children', which was built by Sahas S. of Vijaya High School in 2000. "The idea is to provide mobility to differently-abled children with vision, hearing and movement disabilities. The robot is a moving platform (electric wheelchair) that detects obstructions, movement, passages and doorways. It carries a 360-degree scanning sonar/light sensor array to detect shapes. A speech interface announces the various sensed objects and freeways, audibly. The voice recognition system is under the voice command of the person who can 'talk' to the robot," explains Dr Venkatesh.

Another interesting project is the 'Flexible Arm Pipe Crawler Robot for Noxious Gas Piplelines' built in 2003, by Sahas, then a student of Sri Bhagawan Mahaveer Jain College, Bangalore, and Shreyas S. of MSRIT, Bangalore. Dr Venkatesh explains, "This robot can inspect gas pipelines, both vertical and horizontal, mine-shafts, and other human-unfriendly environments. It carries multiple gas sensors, is equipped with two-way wireless, video eyes and sound sensors. A gripper-manipulator assembly is under wireless control for local repairs, sampling, etc, via video feedback. The robot is extremely flexible and can move even if toppled. The flexible arms can retract or extend to help the robot move along pipes, both horizontal and vertical. The manipulator was also successfully used to cut grass and trim hedges, and modified to pluck white flowers. The robot can also be used to detect land mines and for bomb disposal."

A more recent venture is the 'Cluster Controlled Robotic Master-Slave Army' started by Shreyas S. of MSRIT, Sahas S. of GAT, Avinash V.G. of MSEC, D.R. Nagendrababu of CMRIT and Manajit of PESIT, in 2005. This project will demonstrate the 'Parade Ground' principle of group discipline. A wheeled master robot is accompanied by slave robots, which emulate the movements of the master. Each robot is equipped with infrared (IR), ultrasonic and vision sensors and two microcontrollers. A built-in electronic compass and IR/ultrasound beacon aid the navigation, inter-relational positioning and relative movements of the robots. The master can control the slaves at will, overriding their autonomy, and deploy them for some independent jobs. The master has long-range communication with the control centre and short-range communication with the slaves. It is proposed to provide GPS, and a batterycharging facility at the master robot to charge the slave cells.

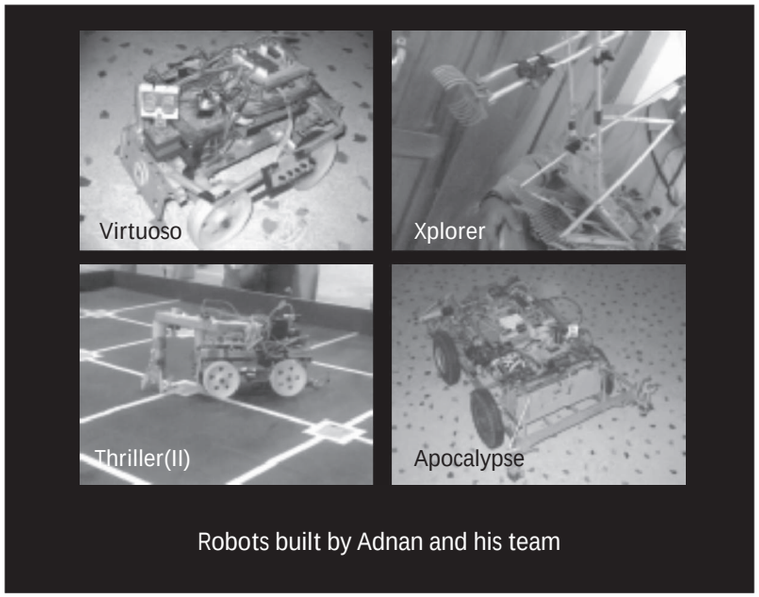
Robotics is not just a man's job!

Chandana Paul's website(http:// www.ifi.unizh.ch/ ~chandana/) contains details about some of her excellent projects.

"I have this link on my Bangalore Robotics group website to inspire girls to take up robotics!" exclaims Dr Venkatesh. Girls, this is worth checking out!

IIT-Kanpur: making robots mobile

"At the Centre for Mechatronics (formerly the Centre for Robotics) at IIT Kanpur, we are working on various aspects of mobile robotics such as wheeled and legged motion, apart from design, path-planning and control," says Susmit Sen, head of the Centre for Mechatronics, IIT-Kanpur. "We are also working on trajectory planning and obstacle avoidance of mobile robots, on the design of hyper-redundant manipulators, robotic



Robots built by Adnan and his team

surgical tools and educational robots. In the area of Artificial Intelligence, the faculty associated with the Centre for Mechatronics, along with the students, is working on natural language processing, speech-activated robots, etc. A group is also working on various aspects of robotic vision such as tracking and cognition of objects, and virtual reality-based robot tele-operation. Some MEMS-based tactile sensors have also been developed, as well as an MEMS (IPMC) actuated finger," explains Sen .

Another interesting project at IITKanpur is the development of a robotic device to assist the anaesthesiologist during surgery. "For patients under general anaesthesia during surgery, any mistake can lead to death, or worse, lifelong disability.

The error rate is as high as 4 per cent in certain circumstances. If a robotic device can be developed to assist the anaesthesiologist, this error rate can be brought down. The challenge is to make a robotic device that is both small enough to be inserted into the mouth, and at the same time, safe and sterile," says Sen. This work is being done in collaboration with the Sanjay Gandhi Institute of Post Graduate Medical Sciences, Lucknow.

We can also look forward to a humanoid robot from IIT-Kanpur. Sen says, "The first part of this work is to develop a dynamic two-legged walking machine. A torso and manipulator arms are to be added later. This work is inspired by the ASIMO robot from Honda. The challenge is to make it lightweight and portable. Issues relating to 'gait' and co-operative robotics need to be addressed."

When asked about what he considers to be the centre's greatest achievement, he says, "While there have been individual achievements by various associated faculty members such as Dr Kalyanmoy Deb receiving the Shanti Swaroop Bhatnagar Award for his work on Evolutionary Robotics, perhaps the greatest achievement from the point of view of the Centre is the development of a bipedal walking machine as part of the Humanoid Robot Project. This is the first dynamic two-legged walker developed in the country."

PESIT Bangalore presents...

Destination: robotics heaven. Team: VENOM. Place: PESIT, Bangalore. The people: Adnan Anwar, Dev Priya, Jagdish Gupta, Prabhanshu Chaturvedi, Assistant Professor Prabhakar Mishra, Professor HN Shankar, and Professor R Muralishankar.

They have built a variety of robots since February 2005 when they formed a team, and have won close to two dozen prizes in tech fests conducted all over the country. Here are just some of the robots they have built.

Virtuoso: An autonomous robot capable of detecting land mines. It can avoid obstacles and is also capable of digging into the sand and removing small iron discs. It is the prototype for a realtime mine-detecting robot, which the team is currently building.

Xplorer: An exploration robot into which obstacle-avoidance capabilities have been incorporated using infrared and sonar. It also features a hybrid model with grid-mapping techniques for mapping the environment around the robot. "We came up with a new algorithm called the 'reconfigurable probabilistic algorithm' for obstacle avoidance, which is computationally less intensive. This feature makes it ideal for mobile platforms," says Adnan Anwar.

Thriller(II): "Thriller (II) is a robotic arm made out of materials lying in the junkyard of our house. The name 'Thriller' stands for the three links present in the arm model. The entire structure can be controlled by a computer or wirelessly, using a remote control. Potentiometers are used for feedback. The idea of demonstrating such an arm is to emphasise the use of junk to make robots as well as to demonstrate a few industrial applications like controlling a machine wirelessly with accuracy," explains Adnan.

Apocalypse: The team's most versatile robot so far, its features include sonar-based grid-mapping and obstacleavoidance features, electronic compass-based control for turnings and Webcambased customised machine vision called 'MachView'. Other features include a wheel encoder and optocoupler-based feedback techniques, distributed architecture and layer-based implementation, an onboard ASUS A7N8X-E motherboard with AMD 64 FX, and wireless LAN connectivity with the master computer. It also has a payload carrying capacity of greater than 50 kg, and RS232 and I2C connectivity among various layers. It can even function as part of a collaborative environment where many such robotic units will do a job collectively, based upon a reasoning method.

Adnan says, "We are currently negotiating with a multinational company. We intend to patent the algorithms very soon. Companies like ATMEL microcontrollers extend their support to us by sponsoring all the microcontrollers used in the robots. Texas Instruments has provided the required samples from time to time, and Honeywell is helping us in our future endeavours."

"Making a machine, embedding intelligence into it, making it fool-proof—all this would be wasted if it was not targeted at an application that can ease human effort. Providing viable solutions to technological problems is what engineering is all about! So, all our machines have been built with the intention of making human life better," says Adnan, with conviction.

"Thriller(II), for example, is a reprogrammable pick-and-place robot which can be used for various industrial applications. The obstacle-avoiding robot taps information about the environment and guides the robot. The process is very similar to giving a blind person a map of the environment in the form of some audible sounds. Work is underway to extend the same logic to guide blind people. We are also in the process of constructing a group of robots to monitor landmines buried inside sand. This robot will help prevent the damage caused by buried landmines to innocent civilians. The idea is to have a group of robots to do the task effectively in the minimum amount of time. All the robots will communicate among themselves wirelessly and work together, relaying live videos of the field and other vital information to the control station. The application can be easily extended to the exploration of unknown terrain by such a team. This cooperative behaviour has long been a field of interest of researchers in this field. Maybe it is time for all the Indian enthusiasts to attack some practical problems rather than focusing on competitions. We all dream big — it's just a question of realising that the 'difference between dreams and accomplishment is purely desire'," he ends on a slightly philosophical note.

Miles to go...

While most of the projects seem extremely interesting and advanced to us, Gagan Goyal, an alumnus of IITBombay (IIT-B) and one of the founders of The Robotics Institute (www.triindia.co.in) explains that most of the projects being undertaken in India are in fact being done by 10- and 15-year olds in the USA and Europe. The reason, he explains, s the lack of adequate resources and opportunities to learn about robotics in India.

"In India, the robotics scenario is totally different; I mean we are really far behind what is going on in developed countries. You take the example of an educational institute, an individual school-going child or a college graduate in India and take a similar person/ institute abroad, say in the USA or Japan. You will find that we are really very far behind. We have done a lot in IT and biotech in the past few years, but in the field of automation and robotics, we are still lagging behind," he laments.

To his credit, Gagan has attempted to remedy the situation as well. "I started TRI to promote the robotics culture among the youth in our country and provide them with a platform to achieve greater heights, so that we can also make our own AIBOs and ASIMOs, and showcase them to the world. TRI is currently focusing more on the field of educational robotics. We will move into consumer robotics later. We are working at the root level now, focusing on school and college-going students. They should get a feel of robotics and robots, and should start thinking that they can do it. It is just a matter of doing it with the right resources. So we conduct workshops to make them comfortable with this field, and also provide kits and components," he says. On request, TRI conducts workshops in schools and colleges for various levels of robotics enthusiasts: roboTRIx for beginners, and iTRIx for more advanced learning.

Vivek Vaid, another alumnus of IITB, was a member of the team that built Natraj, one of India's most famous robots that was built by IIT-B in association with DRDO to help carry nuclear material into reactors which are inaccessible by humans. Vaid echoes Gagan's sentiments: "Indian robot hobbyists have a common complaint—that there are no resources (motors, components, etc) to make the robots (besides the funds of course). I would say that if there are no resources to learn to make practical robots, and if we are suddenly given all the top robot-making resources, we would still not be able to create good field robots because our learning has been on very limited resources."

Robotics enthusiasts, however, seem very proactive. They are taking steps to remedy the situation to the best of their ability. For instance, Robotics India, in partnership with Robonence, will soon be coming up with an online robot store to try and meet the robotics needs of enthusiasts. "Having experienced robotics first hand in India, we will try and create an affordable and accessible place to buy things so that enthusiasts can concentrate on robotics and not run around shops getting ripped," says Vikas Patial.

Latent talent, waiting to be tapped

After looking at their work, if one were to describe the robotics community in India, it would be apt to say that "their enthusiasm is contagious, their knowledge immense, yet opportunities scarce."

It is worth pondering why such a massive amount of latent talent has not been tapped substantially by Indian industry.

FROM SCI-FI TO FACTORIES AND BATTLEFIELDS

Appearances are frequently deceptive, especially when it comes to robots. Contrary to popular perception, robots that most resemble humans are not always the most useful. Robots built to handle specific tasks may not look like AIBO or ASIMO. They may even best range-looking contraptions that move on wheels or tracks, and have formidable tentacle-like arms. But they can perform high-precision tasks, right from assembly of tiny electronic components to keyhole surgeries. Here's a closer look at these real but less-glamorous cousins of the humanoids of science fiction.

The word 'robot' immediately conjures up images of almost-human figures that think, talk and act very much like we do. This is largely due to the conditioning of our perception by authors like Asimov, movies like Star Wars, and TV shows like Star Trek and Small Wonder. In reality, robots may not have hands and feet, and may not even look or behave like humans. But that has not ROBOTS stopped them from making their presence felt in fields ranging from electronics to automobiles.

High-precision assembly of components, hazardous welding, work in areas exposed to harmful radio waves— these are just some of the tasks handled by robotic arms, which work with, well, robotic precision. Robots help in rescue missions, in surgeries, and in the exploration of outer space. They help to load material into nuclear reactors, and in other tasks that require quality, precision and repetition. They even help soldiers on the battlefield.

Whither art thou, robot workers?

Dr C. Amarnath, a professor at IITBombay's Mechanical Engineering Department, is revered as the father of robotics in India. He feels that though the adoption of robots in Indian industry has been very slow, it is only a matter of time before robots are used more widely. "Take the example of Computer Numerically Controlled (CNC) machinery. In the beginning, people were so worried about adopting these. There were the usual labour problems as well. People thought they'd be out of jobs. But now, CNC machines are very common. Similarly, as people start seeing the advantages of deploying robots in factories, they will start using them," he says.

"India is going global and there is a reasonably high quality of manufacturing today. It is hard to expect humans to keep up with such rising quality levels. High precision is required in assembling components into electronic products, and in manufacturing computer chips. Then there are hazardous environments in which it is tough for humans to work. And monotonous tasks like fitting tyres on automobiles, that humans find boring," says Dr Amarnath. "In such cases robots work very well. They ensure consistent and better quality. They work with precision even when a task requires endless repetition. The same high quality is repeated in piece after piece, with no variation."

Dr S. K. Saha, an associate professor with the Department of Mechanical Engineering, IIT-Delhi, says, "In India, the application is at a pretty low level. It can be estimated that about 1000-1500 robots are in use in industrial houses like Maruti, Tata Motors, Samtel, and others, whereas in Japan or USA the numbers could be few hundred thousands. Most of the companies

in India use robots for welding and material handling, in order to avoid humans handling hazardous tasks, and to maintain the repeatability and quality of the precision tasks."

According to Dr Amarnath, Japan is the leader in robot usage. He explains why: "In Japan, they look upon these devices for what they are—machines with certain capabilities. Elsewhere in the world, engineers tend to view robots as a sort of universal automation—all that one has to do is to simply replace the worker undertaking a given task with a robot—albeit an expensive one with sensors, vision and AI. This is like mechanising a farm. In doing so, the farmer realises that the task is quicker if the plants are grown in neat rows, rather than haphazardly—as in the latter case, half the time is wasted in positioning the machine rather than in harvesting the crop.

"In Japan, they are so particular about the use of robots that factories are designed in a robot-friendly way, i.e., with the least obstacles so that robots can move around freely, and so on. The remarkable thing is that sometimes they even design products to suit easy robot operation. Sony's Walkman is an example!" he says.

Making India's men of steel

PARI Robotics Inc at Pune was started in 1990 by two technocrats who returned after graduating from the Renesselaer Polytechnic in the USA. Initially, they found it difficult to convince manufacturers about the need for automation in plants. Today, they are one of the leaders in the automation and robotics industry in India, and have a worldwide customer base with clients such as Ford, Hyundai, Maruti, Phillips, Tata Motors, and so on. PARI has built robots for forging automation (loading red hot billets into the forging press quickly and with least manual intervention); robotic manipulators for manipulating aero models at Mach 4 wind speed and to test various aircraft designs; robots for cutting, welding and handling of steel parts within hazardous and corrosive environments with remote controlled operation; and many others too.

That is how the cookie does not crumble!

If you thought robots are used only for detecting landmines, defusing bombs, working in hazardous environments and handling high-precision tasks in 'serious' industries like electronics and automobiles, think again. Pepperidge Farms has been using parallel kinematic robots to pack their Milano cookies for a long time now. The robots pack more than 1200 cookies per minute. Imagine handling delicate cookies at such a speed, when even human handling tends to crumble cookies if too much pressure is applied. If that does not provide an insight into the precision with which robots can work, nothing can!

Another major player in the industrial robotics and factory automation scene in India is Bangalore based Systemantics India Pvt Ltd. The company is especially known for its SCARA-like pick-and-place robots. SCARA is a robot arm that can work with high speed and precision, and is commonly used in small electronics assembly. It was first developed in Japan in 1978, and made it to Carnegie Mellon University's Robot Hall of Fame this year.

Answering the call of duty everywhere

Robots are also used extensively in defence and rescue operations all over the world. They are used by bomb squads, on the battlefield to detect land mines, to plough through debris and rescue people, and in many other ways. Interestingly, the Indian Army might get extensive help from robots too. In May this year, during the inauguration of the Defence Research and Development Organisation's new building, the Prime Minister announced that, "DRDO aims to create a new range of products and technologies.

Microsoft moves into robot territory

On June 20, 2006, Microsoft announced the launch of Microsoft Robotics Studio, which offers an end-to-end robotics development environment (details at http:// msdn.microsoft.com/robotics/). Microsoft is also sponsoring the development of the Centre for Innovative Robotics at Carnegie Mellon University. The Centre will soon be online at http://www.cir.ri.cmu.edu/, and is expected to be an online destination where, according to company sources, academicians, students, commercial inventors and enthusiasts can share ideas, technologies and software that are critical to robot development. It will utilise Microsoft's new Robotics Studio, a set of software tools designed to easily create robotics applications across a wide variety of hardware scenarios."

These include cutting-edge technologies in propulsion systems, camouflage and stealth technologies, sensors and micro-electromagnetic systems, as well as precision guided munitions, robotics and unmanned vehicle technologies." Robots are also finding application in areas as varied as space exploration and the performance of keyhole surgeries.

Susmit Sen, senior engineer and head of IIT-Kanpur's Centre for Robotics says, "Robotics is evolving at a very fast pace. The focus has now shifted from the industry to the consumer. Till recently, robotics was considered to be an automation tool for improving productivity in factories and other hazardous environments. Consequently, the penetration of robots into our lives was minimal. Robots were also very expensive to build and maintain. However, with the development of microelectronics, software, MEMS (micro-electro-mechanical-systems), sensors, etc, it is felt that economies of scale can bring costs down to a level where robots can be offered to the consumer for everyday use. Various laboratories around the world are working towards integrating control electronics, drives, sensors and software into meaningful systems with real-world applications for everyday use. Robots such as the Sony Aibo are already making a difference to our lives by providing education and entertainment. Many such robots are available as aids to the handicapped and for security applications. Soon, Personal Robotic Assistants will perform all the tasks of a PDA, in response to a voice command, act as security guards and do simple menial tasks such as opening the door after querying and scanning visitors, fetching food items, monitoring your health and communicating with your doctor or your boss."

"Robotics has already made significant strides in space applications. The performance of the two Mars rovers, Spirit and Opportunity, was well beyond expectations. Other robots, such as the Robonaut, which is a dexterous humanoid arm, are expected to be deployed soon," says Sen. "Another area where robotics has made an impact is robot-assisted surgery and robotic surgery. Some examples of robots in this field are: the PathFinder, a stereotactic neurosurgery robot, which can perform keyhole brain surgery; the Zeus System for endoscopic coronary bypass; and Endoassist, the laproscopic surgical assistant.

"MEMS and nanotechnology are significant evolving areas. MEMS sensors and actuators are already in use. Nanotechnology can entirely change the way we do things in the days to come. Quantum computing, for example, can result in a thousand-fold increase in computing power and speed with significant reduction in size. New structural elements such as hybrid organo-metallic parts and self-assembled structures are going to change the way robots are designed and built," he says.

Need-based development

"Ultimately, it is all need-oriented. You build a machine and automate it to do a certain task, and if you want to catch people's fancy, call it a robot," quips Dr Amarnath. "Building robots is not an easy task. It is extremely tough. The space rovers you see on television seem to move fast because they speed up the video. In reality they move extremely slowly, and even to make them move at that speed in unknown terrain is tough. Building robots is also very expensive. So, if there is a simpler way of handling a task with equal effectiveness, then you should try that first."

Students in Dr Amarnath's lab once took up the task of building a robot to help plant saplings on mountain slopes. Planting trees on mountain slopes is very difficult because of the slippery and uncertain terrain, and very few labourers come forth to do it. Therefore, they thought of building a robot for the task. But they soon discovered that it was extremely difficult not only to make a robot that could scale such a tough terrain, but also one that could carry the weight of its own power supply along with that of the saplings! It turned out to be too expensive. "The idea behind building any machine is that it should be affordable and accessible to many. If a machine is too expensive, it won't be widely applicable," Dr Amarnath says.

Incidentally, the students did work out a way to plant saplings. All it needed was some lateral thinking. They ultimately built a machine to plant seeds instead of saplings. And the machine worked on a simple principle—it would slide down the slope much like a rock climber does, by slithering down a rope, stopping at periodic intervals to make a hole and plant a seed! A simple and elegant solution to the problem.

Turn off the hype, deliver value

It is time to stop looking at robots merely as science fiction 'intelligent humanoids' and start recognising them as the programmable and automated machines that they are. Robot enthusiasts would be well advised to stop building 'mecha' men and animals, and instead concentrate on building application oriented and less expensive robots. The latter may not look as attractive but are far more effective and are more likely to be used by people.

WILL MEN AND MACHINES WALK THIS PLANET TOGETHER?

Industrial robots are commonplace today in developed nations like Japan. They may not look like Star Wars robots, but they certainly perform certain tasks with precision. Robots are also making their way into domestic applications. How long will it be before life-like robots end up being a part of our lives? Here's a close look at how robots work, and whether it would be wise to make them more intelligent.

"Jeeves, if you do not like my new white mess jacket, and if you so detest my playing the banjolele, please feel free to seek employment elsewhere. I can always replace you with a robot."

"Pardon me for asking, sir, but can this mechanical being tend to household tasks?"

"Don't be so naïve, Jeeves. Of course, it can."

"And can it douse flames if someone were to unfortunately set fire to your apartment, sir?"

" Don't be an ass, Jeeves. Of course, it can. Rescue robots are a common sight today."

"And would it be familiar with the nuances of language and literature?"

"For the hundredth time, yes! It can do anything that the manufacturers program it to do. And with the developments in Integrated Circuit technology, I believe it's possible to program complicated stuff into robots."

"Then I assume it can also come up with ideas to help people out of tight spots, sir?"

"Dash it, Jeeves! You have put the finger on its one fault. It can't! I believe robots are still a wee bit challenged in the intelligence front. Come to think of it, you can postpone your resignation."

"Very good, sir"

"And lay out the white mess jacket, please."

"I regret to inform you, sir, that the jacket you allude to has been burnt to a crisp along with your banjolele in a sudden fire in your room. As there are no robots at hand, neither could be rescued. Will there be anything further tonight, sir?"

Had P.G. Wodehouse still been penning his amusing and lovable stories on the ways of the British aristocrats, this might well have been a typical exchange between two of his most memorable characters—Bertram Wooster and his butler (or 'gentleman's personal gentleman') Jeeves. And it would, of course, reflect the impact robots are having on our lives today.

Robotics has matured into an important industry and field of study. Robots are quite capable of mimicking several actions and characteristics (especially, predictable and monotonous ones) of living beings, although advanced 'intelligence' still remains a challenge. For those who are still steeped in the Star Wars imagery of robots that effortlessly walk, talk, feel and think like humans, the age of robotics might not have arrived yet. But for those who look at a robot for what it actually is ('a machine which is programmed to move and perform certain tasks automatically,' says the Collins Cobuild Dictionary), robots are everywhere.

"Everybody is naturally very excited about the future of robotics, but they might not realise that robotics is already making a big impact on their lives. It may be quite some time before we can produce a robot butler, for example. There are many advances and new technologies required before we reach that stage. Nonetheless, the current state of technology is finding many uses. The easiest example is manufacturing. Without industrial

robots on the assembly lines, many of the consumer electronics products we love would not exist, and our automobiles would be far less sophisticated. There are lots of other examples, and the list is growing rapidly. So even if the robots of science fiction are not here yet, the robotics technologies are," says Matthew T. Mason, director of the Robotics Institute, Carnegie Mellon University, USA.

Of sense and sensibility

If robots are merely 'machines' programmed to do hazardous or repetitive tasks, what makes them different from any other piece of machinery used in a factory? Well, it is their ability to ape some sensory and motor skills of humans and other living creatures. Robots can get information from the environment and can perform tasks with extreme precision. Advanced robots can often mimic the motor skills of humans or other living creatures, and can react to situations based on preprogrammed rules, which often leads people to believe that robots can 'think and act' like humans. What they overlook is that the robot 'thinks and acts' only as it has been programmed to, by a human.

No fear yet of robots overtaking the human race, but just in case...

It would help to remember the three laws of robotics that Isaac Asimov framed in the 1940s, just in case men and machines start walking the planet together one day.

A) A robot may not injure a human being, or through inaction, allow a human to come to harm.

B) A robot must obey the orders given to it by human beings, except where such orders would conflict with the first law.

C) A robot must protect its own existence as long as this does not conflict with the first two laws.

The sensory abilities of robots are definitely not as advanced as ours, for we have the ability to not only sense things as they are but also perceive and analyse the sensed scene based on experience. That said, robots today can commendably emulate (to a limited extent) the basic senses of sight, sound, taste, smell and touch. In fact, they can even detect some environmental aspects like radiation and magnetic fields, which we cannot.

'Sensible' robots!

A robot picks up hints from the environment and translates these into electrical signals which its 'brain' or processor can understand. Some robots 'see' by detecting the intensity of light in the environment but their working is so conditioned that sudden changes in a situation, even if only a simple glare or shadow, can confuse them. Other robots 'see' by emitting sound waves and detecting the echoes, thereby judging the distances of objects from them. Many robots also have feelers, contact switches and touch sensors with piezoelectric crystals that induce a voltage variation when a pressure is applied. This helps them to detect contact.

Robots can also 'hear,' based on the same principle of picking up sound waves and converting them into electrical seeing or hearing, interpretation of the information is still a challenge, because robots find it difficult to filter out the unnecessary from the critical information.

And truthfully speaking, they are still not intelligent. So, even if they can 'hear,' they can recognise and react to only a limited set of commands programmed in their memory. In that sense, making robots 'speak' is easier, for which it just requires voice synthesisers to convert text to speech. Yet, if robots started talking to their buddies on the telephone, or being vocal about untidy labs, would technologists still be interested in building them?

The "Da Vinci Code"

Leonardo Da Vinci designed a robot or a mechanical man way back in 1459. In the latter half of the 20th century, researchers chanced upon these designs, analysed them using computers, and found that they were indeed designs for a robot that could open and close its jaw, wave its arms, sit up, and move its head. Whether Da Vinci thought of using water or weights to energise his robot, we do not know, but if he had gone ahead and built it, it would have been the world's first robot.

Robots can also 'taste', using chemical, lipid, polymer or peptide membranes, and other technologies that detect the ingredients of a food substance based on how they react on contact with various parts of the membrane. This is quite similar to how our taste buds work. Newer technologies attempt to taste food by detecting the ingredients based on their physical properties. For example, a recent robotic taste detection technology developed at the University of Warwick 'rattles' the ingredients using a sound wave, analyses how the fluid being 'tasted' affects the sound wave, and generates electrical signals correspondingly. NEC Technologies displayed a tasting robot at the Expo 2005 at Aichi. Strangely though, this robot's taste buds were in its left hand, which could detect the ingredients of foodstuffs placed on it, using infrared spectroscopy and pattern recognition. The robot could not only taste food and detect ingredients but also recommend diets to people based on their health condition!

Robots can 'smell' too. Our sense of smell arises out of being able to detect various volatile chemicals in the atmosphere. Advanced robots are fitted with artificial noses that have numerous sensors that detect these volatile substances, using any of several cutting edge technologies. For example, some sensors detect the variation in the speed of oscillation of a quartz crystal that is coated with a material whose mass changes slightly when it absorbs particular volatile chemicals. Some sensors use polymer-coated silicon beams, which bend slightly when they absorb certain chemicals. Others may use vapoursensitive dyes. Whatever the sensing technology used, the detected change is recorded using a computer chip. Then pattern recognition is used to detect the odour and associate a meaning with it.

Mechanical slaves

The word robot is derived from the Czech word robota, which means slave-like labour.

Tactile sense has been the most difficult to incorporate into robots. Robots can easily detect touch, thanks to voltages generated by piezoelectric crystals when pressure is applied on them. But how do robots interpret what they touch? In the absence of light, will they be able to feel around to touch objects and recognise them? Two scientists of the University of Nebraska, Ravi Saraf and Vivek Maheswari, recently demonstrated how the sense of touch can be emulated in robots. They used a thin multi-layered film of nanoparticles of gold and semiconductor materials, with electrodes on either side of the film. When the film touches something, the pressure changes the passage of current, the particles emit light, and an image is formed. The use of nanoparticles makes this extremely sensitive. Depending on how hard one presses the object being felt, the image is sharper or lighter, just as it is with human touch.

The freedom to move

Perhaps the first step that enthusiasts take in the study of robotics is making mechanical objects move. Kids who fit motors into LEGO models, making windmills turn, and block-built men move their arms and legs, are just simple examples. Line-follower robots that detect a clearly visible line on the floor and move along it, and the more challenging stair-climbing bots are among the first that students build. While locomotion seems so simple to understand, applying

it in robots is one of the most challenging aspects of robots. Making robots move with precision, helping them bypass hurdles and enabling them to move through cluttered rooms are all challenges, which though solved, still keep researchers yearning for better solutions.

The number of ways and directions in which a robot can move a joint is known as its degrees of freedom. The human arm has seven degrees of freedom; the optimum degrees of freedom assigned to a robotic arm are six, although advanced robots are known to have as high as 20 degrees of freedom. It is not too difficult to make a robot move using rollers or wheels, but the challenge is to make robots that can walk and climb over hurdles, unaffected by rough terrain that can impair wheel movement.

"Sparing a thought to... thought"

Speaking of sensory and motor skills immediately draws us to the question of intelligence—the sixth sense that triggers all other human actions. Are robots intelligent? If intelligence is merely making sense of inputs and acting accordingly, they are. But even today, the 'thought-process' of robots is limited to the extent it has been pre-programmed. The 'brain' of a robot is a microprocessor that makes sense of various electrical signals generated by the robot's sensory organs and reacts in a pre-programmed way. The simplest technique is the use of rule-based algorithms, which tell the robot, "If condition A, then action B, else C," or more complicated nested 'if-else' structures. Here, the robot only obeys. It cannot learn.

A development on this is the use of neural networks, which add the ability to detect input-output patterns or condition-action patterns, thereby instilling a limited learning ability in the robot. Fuzzy logic, which manifests itself as the 'sixth sense' in several household appliances, is an example of this. A newer technology is the stimulus-response or subsumption architecture that does away with the overheads involved in logical decision-making by directly linking the stimulus to the response. For example, if the robot detects high intensity light in its eye region, it can automatically trigger the arm to move up and cover the eye. The decision-making is bypassed.

Am I talking to a man or a machine?

When can machines be considered to be 'intelligent'? In 1950, Alan Turing suggested a test for this. Place a computer in one room and a human in another. Get a person to interrogate both without knowing who is in which room. The entire communication should be through text messages. If at the end of the session, the interrogator is unable to distinguish between man and machine, then we will have to admit that machines can be intelligent too.

And of course, robots can also compute and do almost anything and everything that a computer can do. So, to a certain extent, robots are artificially intelligent. But can they 'think' and what exactly is 'thought'? Does not thought involve an element of awareness, creativity and independent analysis? With advancements in AI, robots might be able to do these too in the coming days.

Hans Moravec, author of "Robots: Mere Machine to Transcendent Mind", explains in his book and in his numerous research papers that the 1000 MIPS (million instructions per second) power of a home computer just equals the intelligence of a small insect. He predicts that by 2040, a 100 million MIPS processing power will become common. And then, "Robots will be able to speak and understand speech, think creatively and anticipate the results of their actions far in advance. With reasoning power at or beyond the human level, robots will be generally as competent as people."

Intelligent robots—assets or threats?

Now, since we are human, our brain throws the next question at us—would it be wise to create robots with such a high level of intelligence?

"David is 11 years old. He weighs 60 pounds. He is 4 feet, 6 inches tall. He has brown hair. His love is real. But he is not." Remember these lines from the posters of the film A.I. by Steven Spielberg? The story is about a 'mecha' boy called David whose foster 'parents' abandon him when their biological son becomes healthy again. Certain that his mother will love him if he is real, he goes in search of the Blue Fairy to request her to make him a real boy, fully believing in Pinocchio's tale. If robots became as intelligent as predicted by Moravec, would the identity crisis, and the quest for realism and love lead to conflicts between the creators and their creations?

Sherry Turkle, professor of the Social Studies of Science and Technology at the Massachusetts Institute of Technology and founder and director of MIT's Initiative on Technology and Self, writes about A.I. and David.

Karakuri Ningyo

Is that Greek and Latin to you? No, it's actually Japanese. Karakuri Ningyo (mechanical dolls), an ancient Japanese tradition known to have been borrowed from China, is perhaps one of the oldest examples of robotics in the world. Chahakobi Ningyo (tea-serving doll) is an example of robots built based on these ancient designs. When a master places a cup of tea on the tray held by the doll, the doll takes it straight to a guest, waits for the guest to take the cup, drink the tea and place the empty cup back on the tray, and then it returns to the master. Read more about Karakuri Ningyo at http:// www.karakuri.info/

"... the pressing issue is not the potential reality of a robot who 'loves' but the feelings of the adoptive mother in the film—a human being whose response to a machine that asks for nurturance is the desire to nurture it and whose response to a non-biological creature who reaches out to her is to feel attachment and horror, love and confusion. Even today we are faced with relational artefacts that elicit human responses that have things in common with those of the mother in A.I. Decisions about the role of robots in the lives of children and seniors cannot turn simply on whether children and the elderly 'like' the robots ... What kind of relationships are appropriate to have with machines? And what is a relationship?" Considering David to be an inspiration for the future, the Carnegie Mellon University welcomed David into its Robot Hall of Fame (http:// www.robothalloffame.org/) with the moving words "DAVID... for inspiring us with a new vision of future relationships between humans and robots ... and how intense, complex, satisfying, and challenging they will certainly become ... we welcome you, DAVID, to The Robot Hall of Fame!" Now, that is something for robotics and AI experts to think about—how far should they go and where should they stop?

Ordinary robots and extraordinary men

It is obvious that robots are not going to remain mere machines handling hazardous and repetitive tasks, so that humans can be freed from danger and boredom. With advances in AI, robots are likely to act, think and emote like humans. But for now, we leave you with Elbert Hubbard's words, "One machine can do the work of fifty ordinary men. No machine can do the work of one extraordinary man." At least, not yet!