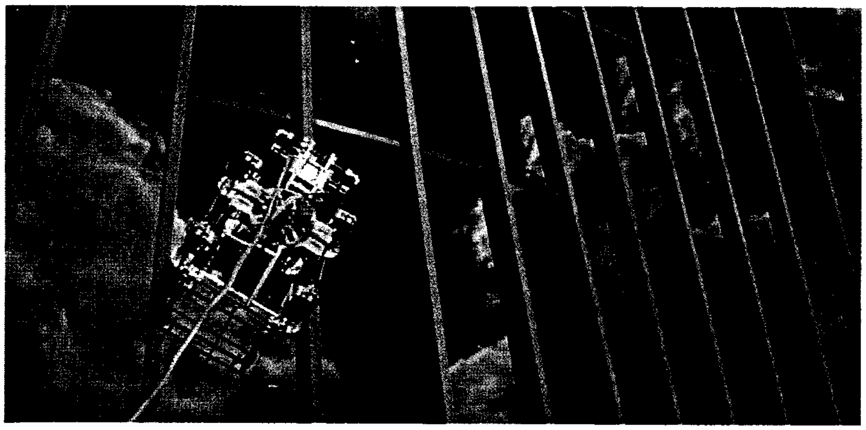
Robots

in Your Curriculum

photo compliments **Sarcos Entertainment Systems (SES), USA** photo compliments **Fraunhofer IPA, Germany**



Above: Billboards are static outdoor advertising. Adding movement to outdoor advertising helps it get noticed. Fraunhofer IPA combined a climbing robot with advertising to create "animated ads."

Climbing Robots

Climbing robots are often used in situations that are too difficult or too dangerous for a human worker. They can perform construction or reconstruction work in hard-to-access spaces as well as inspection work in hazardous environments, e.g., in nuclear power plants. They also use their special abilities to clean or paint vertical surfaces. Most of today's climbing robots use vacuum grippers, relying on negative pressure to generate an adhesive force to the climbing surface. It is easy to see how different disciplines, such as material science or vacuum techniques, are needed to support the development of cost-effective and reliable products.

A closer look at prototypes and working products shows that the mobile platform is generally based on one of three systems: a sliding frame system, a multi-legged system, or a caterpillar system. A sliding frame is made up of a minimum of two platforms that can be displaced against one another. Each platform is equipped with its own gripping system. While the gripping system of one platform ensures a firm hold on the surface, the other platform is moved upward. The gripping system of the platform that was shifted then takes over the gripping function, and the first platform can be advanced. Multi-legged systems take their inspiration from nature: As one or more legs are gripping the surface, other legs are moving ahead. As they contact the surface, they grip and the other legs can continue to move. The caterpillar system is similar to that of a tracked vehicle, with a continuous line of grippers instead of a tread.

Although the technology for climbing on vertical surfaces has been significantly advanced, climbing robots are still not widely used for two reasons. First, most of today's commercially available climbing robots have an insufficient payload-to-weight ratio. Second, all of the most recent developments have been engineered for one very specific task, ignoring the possibility of a wider range of applications.

Driven by customer demands, a new approach is being developed. A climbing robot should not only be able to perform the task, but perform it economically. Moreover, it should also be able to perform a variety of tasks so that the return of investment for the customer is improved. This leads to two challenges: An appropriate climbing robot should be lightweight to improve the payload-to-weight ratio and it should also be modular to allow it to be used for different applications.

An interesting project that combines technological innovation with publicity is the so-called "animated ad". In order to get funding for innovative climbing robot developments, Fraunhofer IPA's engineers have invented a new type of climbing robots—advertising robots. Exterior advertisements are a permanent fixture in the modern world. Affixed to the facades of buildings, these advertising methods are motionless, and after our eyes become accustomed to them, we no longer notice them. If the advertisements were to be constantly moving, however, they would catch people's attention over

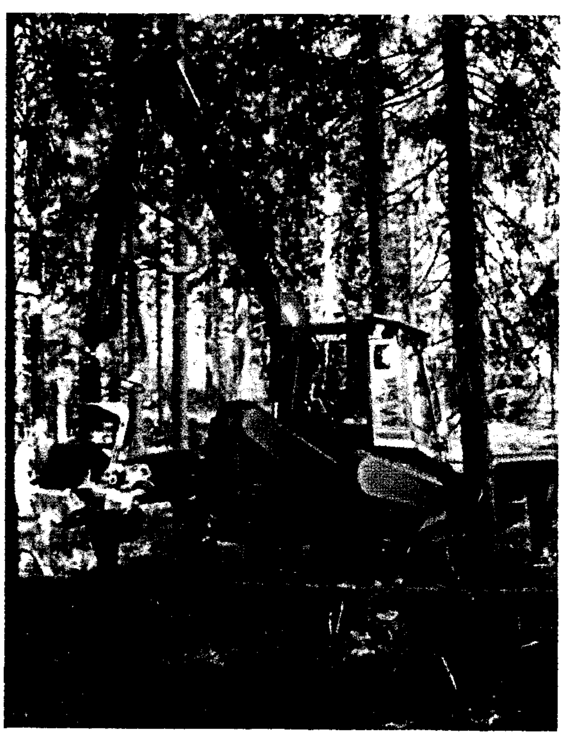
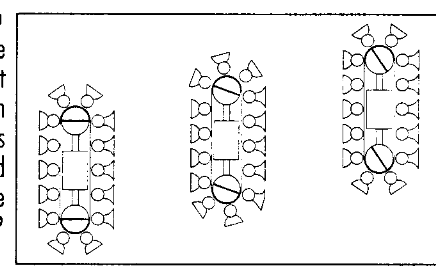
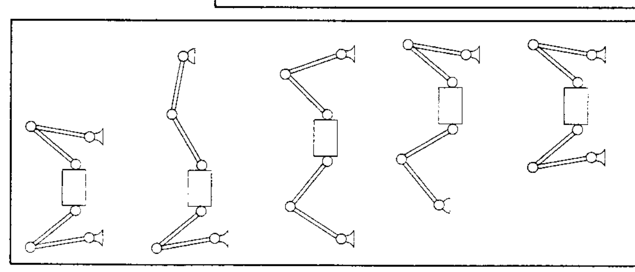


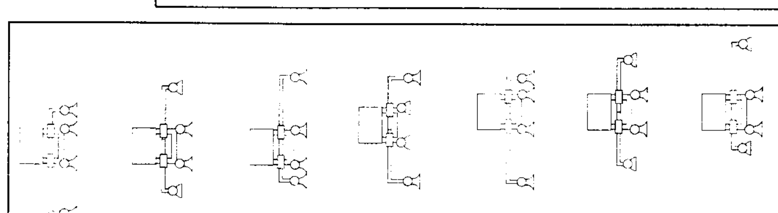
photo compliments **Plustech Oy, Finland**

Right: Some robotic movements are inspired by nature. The animal that inspired the caterpillar system (top right) is obvious, but what was the model for the multi-legged (center right) and the sliding-frame (bottom right) systems?



Left: While not technically a service robot, Plustech's ingenious six-legged walking kinematics has potential for service robots.





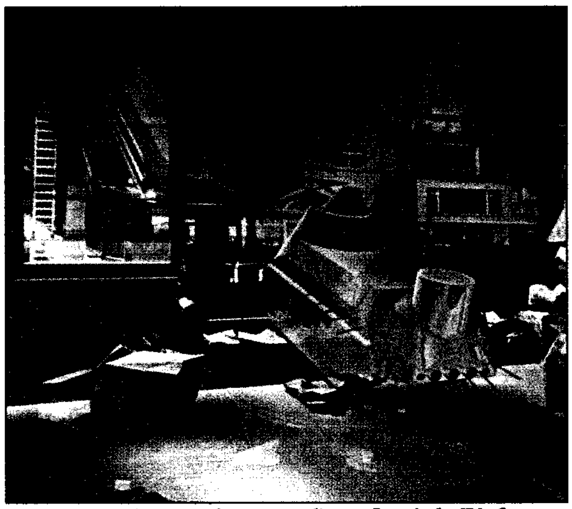
and over. Fraunhofer IPA's engineers have created advertising robots by combining a modular climbing robot with an advertising and information carrier. This synthesis will surely gain in popularity within the next few years.

Due to the modular type of construction, a variety of designs is feasible, all depending on the carrier system and the payload. The carrier system is made up of modules for adhesion, motion, drive, and control. The modules are characterized by their decentralized intelligence. The frame is made up of high-tensile carbon fiber sandwich tubes. Specially engineered connecting elements provide a high level of flexibility. The first prototype is equipped with a very light display manufactured by E Ink Corporation in Cambridge, Massachusetts. This company has invented an electronic ink display that combines high visual impact, extreme thinness, high curvability, wide viewing angle, and a minimum power draw with an extremely lightweight construction. One square meter weighs less than one kilogram.

Firefighting Robots

Another extremely dangerous task is firefighting. Several firemen died during this year's huge brush fires in the United States. In case of a fire, the first priority is always to gather information on the scene of fire as quickly as possible. However, in most cases the problem is that firemen cannot get close enough to the source of the fire because of extreme temperatures—several thousand degrees Fahrenheit. This problem occurs not only in brush and forest fires but also in large-scale warehouse or tunnel fires.

Service robots can help. An innovative approach in tele-operated firefighting is to use a tracked vehicle equipped with cameras and sensors to gather information. What is actually burning? Is it hazardous material? May the firemen use water to extinguish the fire or would that make the situation worse? These questions need to be answered before a fireman enters the area of the fire. In order to execute this difficult task, the firefighting robot needs to be equipped with a variety of sensors that are able to gather the necessary information and provide initial interpretations. It also needs, of course, a heat shield to protect itself. If the robot is able to access the area of the fire it could then deploy an autonomous reel. A reel is a two-wheeled frame carrying a drum around which the firefighting hoses are wound.

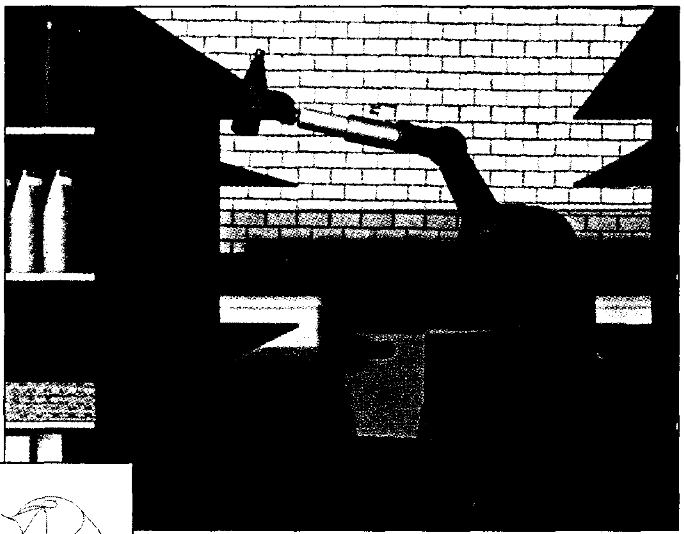


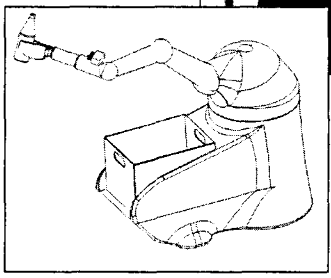
Images compliments **Fraunhofer IPA, Germany**

Top: The fire-fighting robot of the future will be able enter areas fully involved in a fire and collect information on the nature of that fire even when hampered by thick smoke. These robots will be equipped with infrared cameras, radar sensors, laser scanners, ultrasonic sensors, tactile sensors and external sensors (e.g. gas sensors) that can help determine what materials are burning—critical information for picking appropriate extinguishing agents.

Bottom: The remote hose-reels robots are equipped with heat sensors that allow them to autonomously adjust their nozzle output and direction to the areas that need it.

images compliments **Fraunhofer IPA, Germany**





Above: A picturial drawing of a supermarket multitalented robot helper and a three-dimensional rendering of that machine at work. The robot could stock shelves or retreive orders when the store is closed to customers.

Equipping the reel with heat sensors and actuators would enable it to autonomously adjust the extinguishing agents towards the fire.

Such a robotic system will soon be available, and fire departments of major cities such as Los Angeles and Tokyo are interested in such a device. Firemen are heroes, but even heroes need the right equipment to save lives.

Flying Robots

Not all service robots are earthbound. Micro Air Vehicles (MAV) seem to have escaped from a Bond film: A mini-aircraft developed by Aerovironment of Simi Valley, California, represents the current state of technical feasibility in the area of miniaturized air reconnaissance. Aerovironment's Black Widow can stay airborne for over 16 minutes; that's not in the laboratory, but outside! The remote-controlled battery-powered mini-plane can reach speeds of nearly 70 kilometers per hour. The next generation will be equipped with a GPS navigation system, sensors for stabilizing flight automatically, a magnetic compass, an altimeter, and a speedometer—all integrated on a disc with a diameter of just 15 centimeters. The micro-motors that provide the necessary thrust are manufactured by the Swiss company RMB. The smallest industrially manufactured electro-motor weighs only 0.3 grams—less than half the weight of a paperclip! All this demonstrates the broad expertise and interdisciplinary cooperation in the development of truly workable service robots.

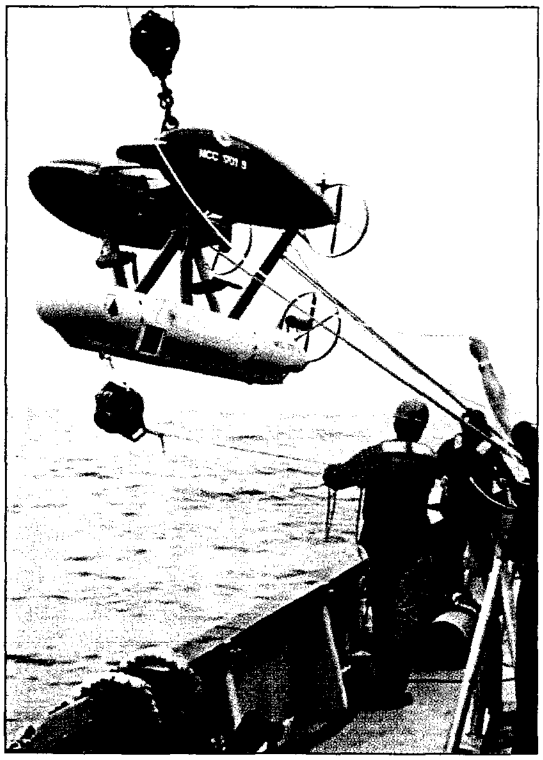
Animatronic Robots

Another kind of service robots has already shown us its talents: The animatronic robots. Monsters have been part of cinema history from the earliest days. Some, like King Kong and Godzilla, are even celebrities in their own right.

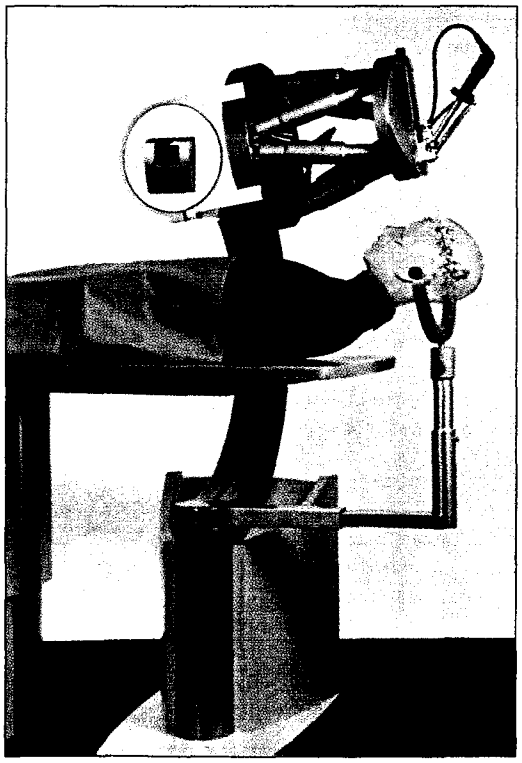
Even though computer animation has allowed special effects to become almost perfect illusions, it would be a mistake to think that puppets and models are going to disappear from the producer's bag of tricks.. The real superstars putting fear in viewer's hearts are deceptively realistic reproductions of monsters, in whose veins hydraulic oil rather than blood flows. Their computer brains have the power of a mainframe, and their bones are made of high-grade steel, aluminum alloys, and the most up-to date compound materials.

Hollywood's dream factories swear by the entertainment robots that are created by the two California-based companies Stan Winston Studios and Edge Innovations. When it comes to water creatures, Walt Conti's team at Edge Innovations is the first choice. The whale Willy that conquered our hearts in Free Willy was a robot engineered by this company. In Columbia Tristar's thriller Anaconda, the twelve-meter-long giant snake was a

Right: The ABE (Autonomous Benthic Explorer) was constructed at the Advanced Engineering Laboratory at the Woods Hole Oceanographic Institute (WHOI), Woods Hole, MA. The ABE can dive to 4,500 meters. It can position itself a few meters above the ocean floor and navigate for up to 100 kilometers. From the depths, its sensors can record video images, salt concentrations, temperature, magnetic fields and the distance to the ocean surface.



Far right: The endoscope and navigation robot Operation System 2015 was developed by Fraunhofer IPA to assist surgical operations in the micrometer range.



fully functional animatronic device with 60 vertebrae driven by hydraulic cylinders. And what about Deep Blue Sea? Well, these sharks were also fake, but Edge Innovations' creatures helped the actors to get real sweat on their faces.

Service Robots in the Future

What can we learn from the above-mentioned pilot applications? Service robots, unlike industrial robots, have a wide variety of applications and an even wider variety of designs. Therefore, there is a big demand for advances in technology in order to push service robot developments. For example, materials that will revolutionize service automation products are "intelligent" active materials that will "sense" a change in their environment and then react autonomously to this change. These so-called adaptive structures will be the key towards highly integrated robotic systems.

But "adaptronic" materials are not the only advances that will accelerate service robot developments. Information processing units have developed cycles that are far beyond our imagination. Every 18 months computational power is doubled. Today's palmtop computers weigh less than a pound and run for several months on two batteries. It is even possible to buy a PC-on-chip for $100 with Ethernet and field bus interface. We anticipate that new ways of computing like optical computing, quantum computing, or DNA-based computing will help to improve the performance of service robotic systems.

Another key concern is the power supply, a fact that is true for all mobile systems. Power consumption is naturally related to the efficiency of the drives that are dependent on the power supply. New batteries will improve the level of autonomy; however, for more radical changes new lightweight high power drive systems with a high efficiency will have to be developed.

In order to become widely used, service robots must be more "intelligent" and easy to interact with. Engineers throughout the world who have devoted their work to the fascinating world of service robots have focused their attentions on this challenge. Just like the locomotive, the automobile, plastics, and television and mobile phones, the service robot could establish itself in the mainstream of information and communication technologies as a mass-market product by the beginning of the twenty-first century.

Technology teachers are in a crucial position where they can inspire and teach young people to meet these challenges. Without their devotion to continued education and their dedication of time and energy, progress will be slower. Support for these educational efforts will pay high dividends for the economy of any nation that makes the investment.

Gernot Schmierer is the Group Manager Robot Systems for Fraunhofer IPA, Stuttgart, Germany. With Rolf Dieter Schraft, he coauthored *Service Robots*, for A.K. Peters. (For more information see page 28.)

volcano that is threatening to erupt. Use LEGO, K'NEX, Robotix or another modeling system. One team should construct the mountain and volcano. This group could use the Internet to learn how to produce a simulated volcano and about the data scientists studying a real volcano would want to gather—critical information for the robot design team.

briefs

❶ ***From the initial idea to the product definition:*** Visualize your idea, describe it to your colleagues, try to analyze the service robot's task and the service robot's environment, the result of this initial step should be a list of requirements the service robot needs to fulfill. Additionally, try to define quality characteristics. What does it mean for you to perform the desired task in an optimal way?

❷ ***From the product definition to feasible concepts:*** Make a functional analysis of your system and try to split your system into subsystems/subfunctions. It is easier to solve a lot of small problems in a team than to address the complex system all at once. "Assemble" your concepts and make an assessment for your concepts. Determine your favorite concept.

❸ ***From the concept to the product/prototype:*** Design subsystems and parts. Where necessary, make computer simulations before the manufacturing process starts. Tests and optimization loops are mandatory. Dedicate to perfection! Integrate your components into the final product/prototype!

..... and don't forget to have fun during this process!

Special thanks to Henry Harms (South Carolina) and Gernot Schmierer (Germany) for this design brief.