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"There is a single light of science, and to brighten it anywhere is to brighten it everywhere..."
-Isaac Asimov

New Jersey Institute of Technology

Moving the Edge

New Jersey Institute of Technology is one of the nation's leading public polytechnic universities. It prepares students to be leaders in the technology-dependent economy of the 21st century, offering degrees in more than 125 undergraduate and graduate programs.

NJIT has consistently been recognized as offering an exceptional return on investment through its affordable tuition and its high average starting salaries. NJIT's multidisciplinary curriculum and computing-intensive approach to education provide the technological proficiency, business know-how, and leadership skills that future CEOs and entrepreneurs will need to succeed. With an enrollment of more than 10,000 graduate and undergraduate students, NJIT offers small-campus intimacy with the resources of a major public research university.

Albert Dorman Honors College

Engaging the Future

This year, the Albert Dorman Honors College is celebrating its 20th anniversary. Named for Dr. Albert Dorman, the only person to have been voted both a Fellow of the American Institute of Architects and an honorary member of the American Society of Civil Engineers, the Albert Dorman Honors College today attracts top-performing students from New Jersey and across the country.

The Albert Dorman Honors College provides a uniquely rich and challenging educational experience to these students. The Honors experience prepares these students to be tomorrow's global leaders, problem solvers, and innovators who are recognized for their integrity, professional excellence, passion and compassion, and service to the community. Students participate in individualized curriculum rich in Honors courses, colloquia, study tours, dual degree paths, and study abroad opportunities. What will your path be?

Contents

Letter from the Editors

Dear Reader:

Robotics is a field of technology that is involved in creating and implementing robots in practical applications. This field is a current and ever-evolving one, intimately interlocked with software and artificial intelligence, and constantly seeking to find innovative solutions to both old and new problems. With robotics, humans have been able to reach and exceed limits previously thought unsurpassable. The future is bright, and understanding current issues will help guide the next generation of robotic technology.

There are multiple ways of looking at this fascinating field. One can investigate the human psyche, examining people's response to robots and how perceptions of life or "alive-ness" are changed through inanimate objects that seem real. Or, one can take the strictly engineering route, examining the mechanics of robotic parts and how current software has advanced robotics far beyond its former capabilities. The approach taken in this issue of the *Technology Observer* seeks to combine both views and expand in multiple and diverse applications of robotics, in areas such as medicine, sports, industry, outer space, rescue missions, and others, which are too numerous for a single issue to cover. However, through examining such a range of robotic applications, one can gain a greater appreciation for bringing the technological adaptability of a single concept—robotics—into a slew of disciplines.

This year also saw changes in the format of the articles. Unlike before, we leaned towards shorter articles in order to present readers with a larger range of topics in the rapidly expanding field of robotics. In achieving this end, we hope we have been successful.

There are many to whom we owe our thanks for making this issue a success. First, we would like to thank Dr. Shivon Boodhoo, Director of Special Programs and our advisor, for her continuous guidance and support throughout this process. We would also like to thank our new advisor, Dr. Regina Collins, who has recently joined the staff of the Albert Dorman Honors College as the Associate Director of Writing, Communications, and Outreach. Dr. Collins is, in fact, an alumnus of NJIT, from a Bachelor of Science in Computer Science through a Master's in Professional and Technical Communication to her doctorate in Information Systems. Her careful and constructive review of the articles has been invaluable to this issue. We also extend our sincere gratitude to Dean Passerini and the Albert Dorman Honors College. Lastly, this issue of the *Technology Observer* would not have been possible without our team of dedicated editors, writers, and designers.

We hope you enjoy reading this issue of *Technology Observer* as much as we enjoyed creating it.

Sincerely,

Jeremy Jen
Pooja Banginwar
Editors-in-Chief

Letter from the Dean

Dear Reader:

With the Honors College celebrating its 20th anniversary, and the *Technology Observer* reaching its 14th edition, the students had an opportunity to rethink the format and the organization of the magazine. This student-led publication has transitioned to a new approach composed of more, shorter articles exploring groundbreaking topics and disciplines. As the team of contributors grows larger, the opportunities to span across various boundaries are amplified. The diversity of the articles presented in this issue is an example of such expansion.

The theme of this issue is "robotics" which is a field generally associated with engineering and manufacturing applications. Yet, in this issue, only one article addresses the impact of robots in manufacturing (see Sahitya Allam's piece on "Baxter, the industrial robot"). Sahitya's piece describes an interesting and versatile, almost human-like, member of the production and assembly chain that may potentially bring back the ability to compete with low-wage manufacturing countries. In the age of mass-customization, Baxter could handle low volume and high mix manufacturing jobs using its array of sensors that enable it to halt production if errors are detected.

However, while robotics and manufacturing have been intimately connected for the last several decades, most of the articles that our Albert Dorman Honors scholars chose to focus on go well beyond the typical production chain. They discuss innovative applications in disparate fields, especially medicine, space exploration, emergency management, and law enforcement. The articles are brief but quickly address shortcomings and limitations of each application: from lack of affordability to unintended uses and even to limitations of bionics and visual systems. While the level of approximation is staggering, robots are not humans, not yet. A complex system of cameras and sensors may signal the existence of a new stop sign, but in real danger situations, automatic cars still need to revert to manual pilots (see "Putting the auto in autonomous" by Saad Ali).

And this is where articles such as "Robots in music" by Hari Rao remind us that robotic metal bands such as Compressorhead cannot recreate the nuances and emotions that are generally the strength of live music performances. The robotic ability to adapt and adjust to the audience's needs and moods is still under development. With the advancement of neural networks and self-learning computational systems, however, we might not need to wait too long.

The innovations described in this issue show that robots of all sizes (microbots for laparoscopic surgery or macrobots for earthquake rescue) extend human reach by lowering chances for error, preventing health and safety risks, and even venturing into areas unsafe for humans. Space applications enable robots to complete surgical procedures remotely if astronauts fall sick. Alternatively, they eliminate the need for astronauts altogether by extending the length of space missions, operational life, and ability to react to adverse conditions (see the article on "Space robotics" by Chaitali Gandhi).

The extension of human capabilities, such as in sports applications that mimic the performance of the best athletes ("Robots in Sports," again by Hari Rao) is not only outward-focused (augmenting and extending reach outside of the human body). It is also inward-focused and requires creating connections between brain signals, nerves and visual and auditory devices that are implanted in humans to recover lost functions. The biological process known as "re-innervation" reassigns lost functions to new nerves using prosthetic technology that enhances the ability to feel objects and exploit the neural re-activation of nerves and muscles. The articles by Daniela Davison, Amin Golamy-Sadig, John Palmieri, and Rebecca Deek discuss this brain/human body connection and their interactions.

From biomedical engineering, computing, chemistry principles, physics, electrical engineering, managerial, design and artistic applications, this issue on robotics truly represents the richness and multidisciplinary focus of the New Jersey Institute of Technology. The Albert Dorman Honors students are ambassadors of this diversity and celebrate it by creating links across topics and disciplines. The students chose the topics based on their major or particular interests, and painted an interesting picture of what is next for our generation.

All the articles I read in this issue made me think about current and future possibilities, but one article was particularly interesting and a cause for reflection. There are substantial benefits, as indicated by the cited studies, that show the positive impact of robo-pets on an elderly and aging population (see "Paro-peutic Happiness" by Sahaana Uma). Nevertheless, one should be mindful of not using robots as substitutes for fundamentally human functions such as affection, empathy and caring. And, while I might really like a pet that I do not need to take out for a walk, I dread the day when grandchildren will send robots to visit grandma and grandpa.

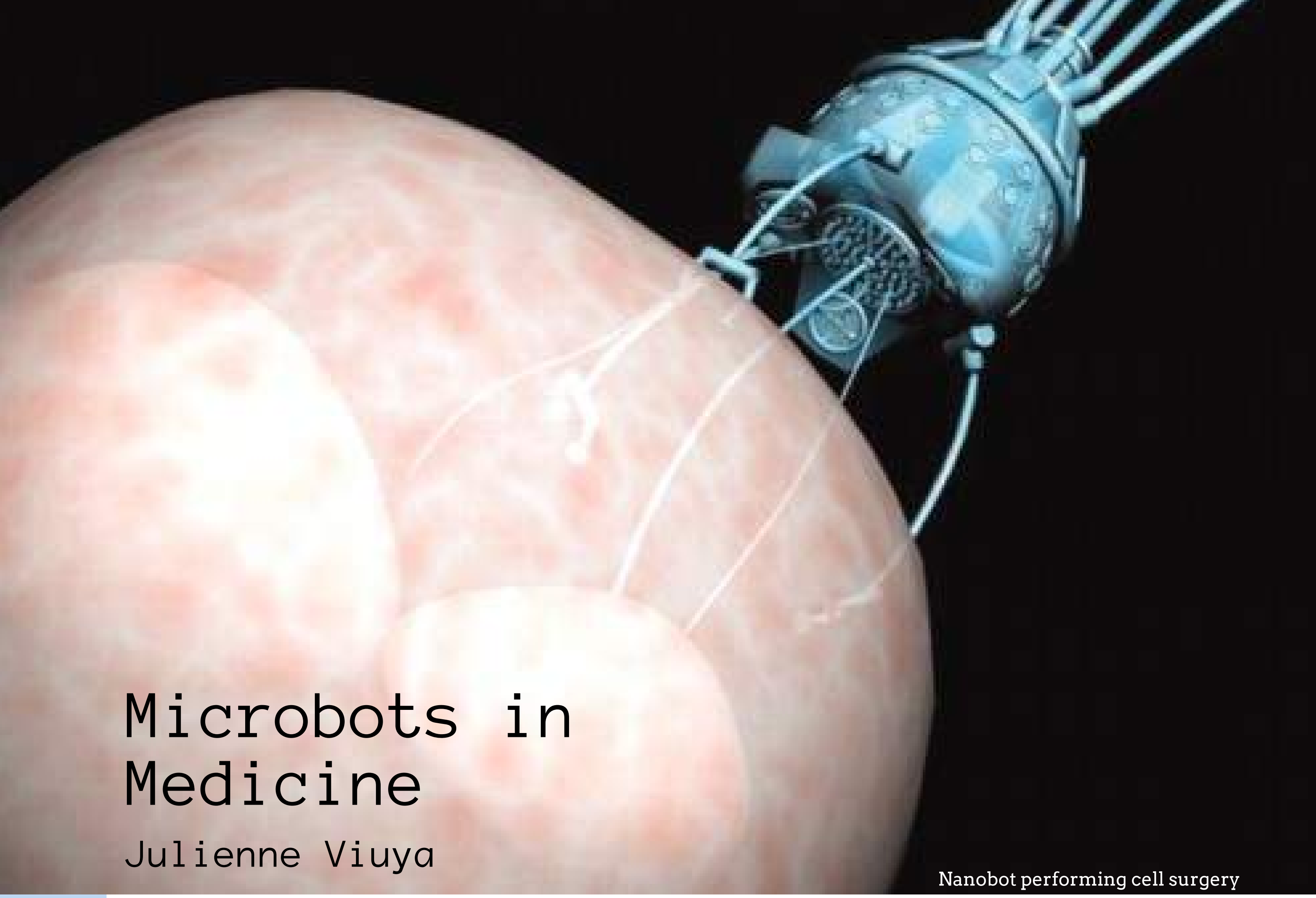
This issue is a celebration of technological progress and innovation. Let's remain vigilant and emotionally ready for the unintended consequences of such progress. As Honors scholars, you will have the knowledge, skills and empathy to drive such progress in alignment with ethical, social norms and values that should govern our society.

Most Sincerely,

Katia Passerini, PhD, PMP
Dean, Albert Dorman Honors College
Professor and Hurlburt Chair of Management and Information Systems

Microbots in Medicine

Julienne Viuya



Nanobot performing cell surgery

Robotics has advanced on both the macroscopic and microscopic level. At one end of the spectrum, robots are designed for large-scale projects usually requiring several people; at the other end, there are robots designed for microscopic tasks too intricate for a human hand. Robots created for tasks at this scale are called microbots or nanobots depending on their size. Microbots are valued because their size allows them to perform actions at a microscopic level with precision, bringing exciting advancements to the field of healthcare. In fact, they have been successfully used to carry out minuscule surgeries in environments such as blood vessels. Microbots can also be assembled to work together in large numbers to form a “swarm” that can be directed towards a target. In these ways, microbots can achieve paramount advancements in medicine.

In the complex processes of surgery, there is no room for error. The human body can be hostile and unforgiving to foreign material or a wrong incision. The scary truth is that minute details of a surgery can have long-term effects on the body. Thus, modern medicine is exploring the use of microbots to reduce the risks and increase the accuracy of surgery, as well as to improve the capabilities of prosthetic limbs.

However, the scope for microbots does not end there. Microbots have also been found to have exciting applications in eye surgery. One of the most complex organs of the body is the eye, and given the delicate and complicated nature of this organ, surgeries on the eye require great precision. To facilitate these procedures, the Multi-Scale Robotics Lab (MSRL) at ETH Zurich has been working on developing microbots for eye surgery.[3] Microbots, because of their small size (285 micrometers in diameter), minimize the size of incisions and reduce the opportunities for error, leading to minimally invasive surgery. However, size also poses a limitation because microbots cannot be fitted with a motor or batteries to control or power them. Because of this limitation, MSRL has developed a means to externally control microbots through a magnetic field created by a device called the OctoMag. This system was initially tested in the eyes of pigs, and later in the eyes of rabbits. Both trials were successful and proved that microbots could successfully perform minimally invasive surgery in the eye. Now, MSRL continues to develop and refine this system to prepare it for clinical trials and expand its applications.[3]

When a part of the body suffers injuries beyond repair, the best available option, in many cases, is replacement. The field of prostheses is not new. For example, wooden legs have been used for centuries. However, the capabilities of such artificial limbs are limited and the comfort of the user is also compromised. Therefore, people continued to search for better materials, improving upon previous ideas one step at a time. Now, prosthetic limbs have advanced to the degree that users can have full control over their prosthesis just as if it was part of their own body. For example, prosthetic arms now allow users to have full control of the prosthetic fingers and lift and hold objects.

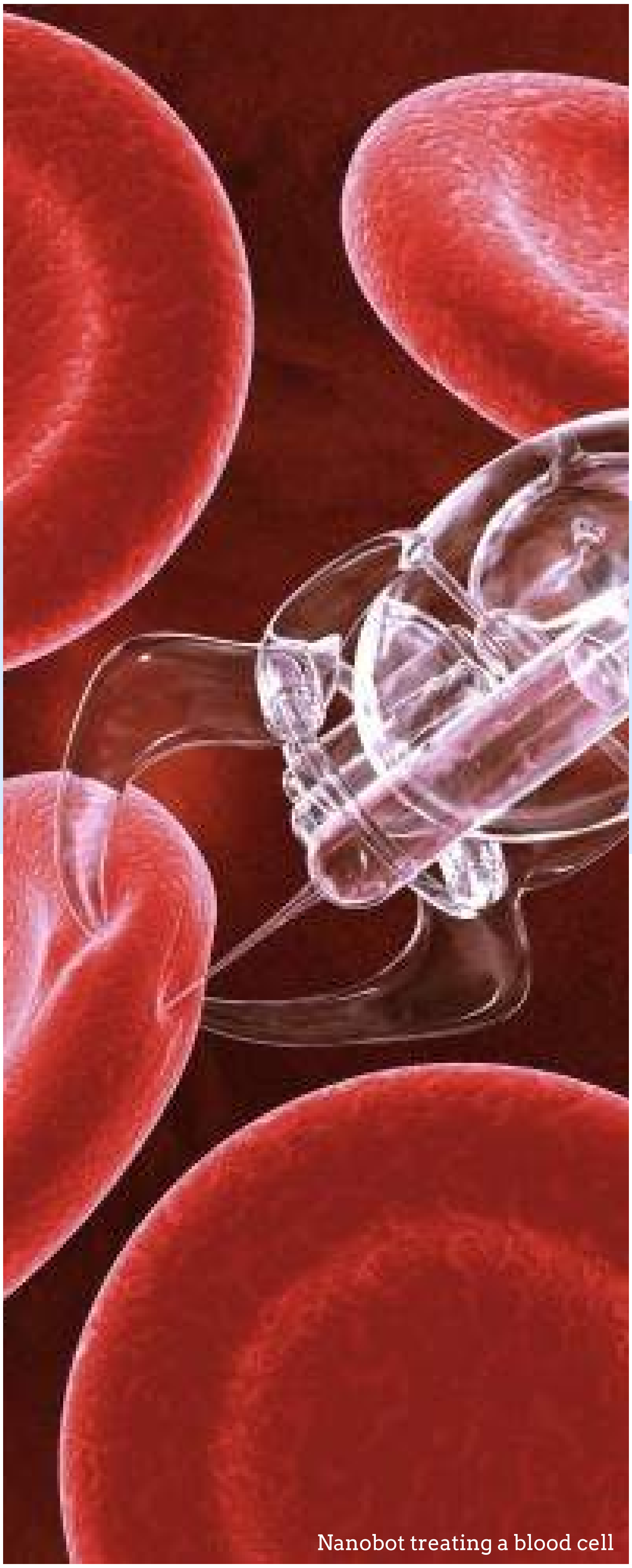
"With the new technology offered by microbots, medicine or toxins can be delivered to target cells instead of generalized in the body."

It may seem that the field of prosthetics typically involves large robotic mechanisms, but a team of researchers at the University of Michigan are actually experimenting on creating prosthetic muscles out of microbots.[1] A damaged muscle can be replaced with these microrobotic muscles, formed by a swarm of microbots working together in chains. Michael Solomon, a professor of chemical engineering at the University of Michigan, and his research team have been developing gold-plated microbots that can form a chain using an electric field to lengthen the particles. The microbots are created in an oblong football shape, with only one side of the "football" gilded in gold. This metal gilding allows an attraction between the microbots when an electric field is applied. [1] Once the electrical current is turned on, the microbots assemble into a chain that runs parallel to the field. The chain is then manipulated by the electric force to form the muscle-like fibers that essentially expand and contract like the fibers of a muscle. However, these microrobotic muscle fibers only create one-thousandth of the force created by natural human muscle fibers. Consequently, this idea will require further development for use in large robots and, hopefully someday, humans.[1]

At the microscopic and cellular level, the human body becomes increasingly complex. Individual tissues and cells have unique needs. The ailment of one tissue or group of cells may not be shared by the next, and therefore treatment cannot be generalized, especially when treatment can be particularly harmful. In the example of cancerous cells, the tumor is made up of a mass of abnormally growing cells that are usually surrounded by healthy cells. Thus, when chemotherapy and radiation are used to treat cancer, oftentimes the toxins also harm healthy cells and cause adverse side effects. With the new technology offered by microbots, medicine or toxins can be delivered to targeted cells instead of generalized in the body. The microbots, specifically referred to as microcarriers because they carry medicine, are controlled using a magnetic field produced by an MRI machine. The lab conducting this research is the NanoRobotics Laboratory at the École Polytechnique de Montréal.[2]

In addition to the administration of medicine at the cellular level, microbots can also be used to collect data on glucose levels of the body. Through this application, microbots would be used to monitor and regulate diabetes. These microbots would be injected into the bloodstream and allowed to travel passively while collecting data and exporting it to an external source. This specific research has been developed by a team in Australia. In this application, the microbots are used to operate on the body at a cellular level, thereby influencing the body as a whole.[2]

As the field of microrobotics grows, new possibilities are emerging, especially in the field of healthcare. Yet, there are still challenges to be addressed. Using microbots in surgery is still more expensive than traditional surgery, and further research is required to better control them. However, with the pace of development, microbots will undoubtedly play an important role in the future of healthcare.



Nanobot treating a blood cell

ROBOTS IN SPORTS

HARI RAO

The RoboCup: Soccer

The purpose of sports is to showcase the most physically competent human specimens on the planet, while providing entertainment value for spectators. Whether it is an individual or team sport, the best players are generally believed to be the most highly trained in their respective positions. Thus, it is natural for engineers to attempt to emulate the greatest physical feats of humans with their own mechanical creations. Often times, mechanical structures are made to accomplish feats that go beyond what ordinary humans are capable of, such as robotic cranes reaching incredible heights or lifting immensely heavy objects. However, mechanical and robotic structures can also be created and used to provide humans with challenges to help them improve their current level of physical ability.

One of the earliest ideas in sports robotics was an automatic ball launcher, often used in sports such as baseball or tennis, that automated a small portion of what an opponent would do. Advancements in robotics research have elevated the ability of these motorized opponents. In Japan, an unknown company has developed a mechanical soccer goalie. The robot utilizes a large metal apparatus that is set up around the goal. Cameras stationed around the metal rig examine the flight of the ball as it approaches the goal while network-attached computers trigger the "goalie" to respond in real time to stop the incoming shot.[1]

The goalie stands with extended "arms" and simply floats left or right on a single plane of motion to block the incoming shot. Tools like these demonstrate not only the advancements in robotics that have occurred over the years, but also how the evolution of these innovations helps athletes train to become even better. The robotic goalie performs remarkably well, and several videos online show that even the soccer legend Lionel Messi has had difficulty beating it. Although this is certainly impressive, the question still arises of whether it is possible to create robots that truly achieve levels of athleticism and coordination comparable to that of human athletes.

The RoboCup was founded in 1997 as a way to promote "robotics and AI research by offering a publicly appealing, but formidable challenge."[2] The ambitious goal of the RoboCup is as follows: "By the middle of the 21st century, a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup."[2] The RoboCup has become quite popular, and videos of past competitions are widely available online. Comparing the robots from past years to ones in recent years, the improvements in dexterity and functionality are clearly visible.

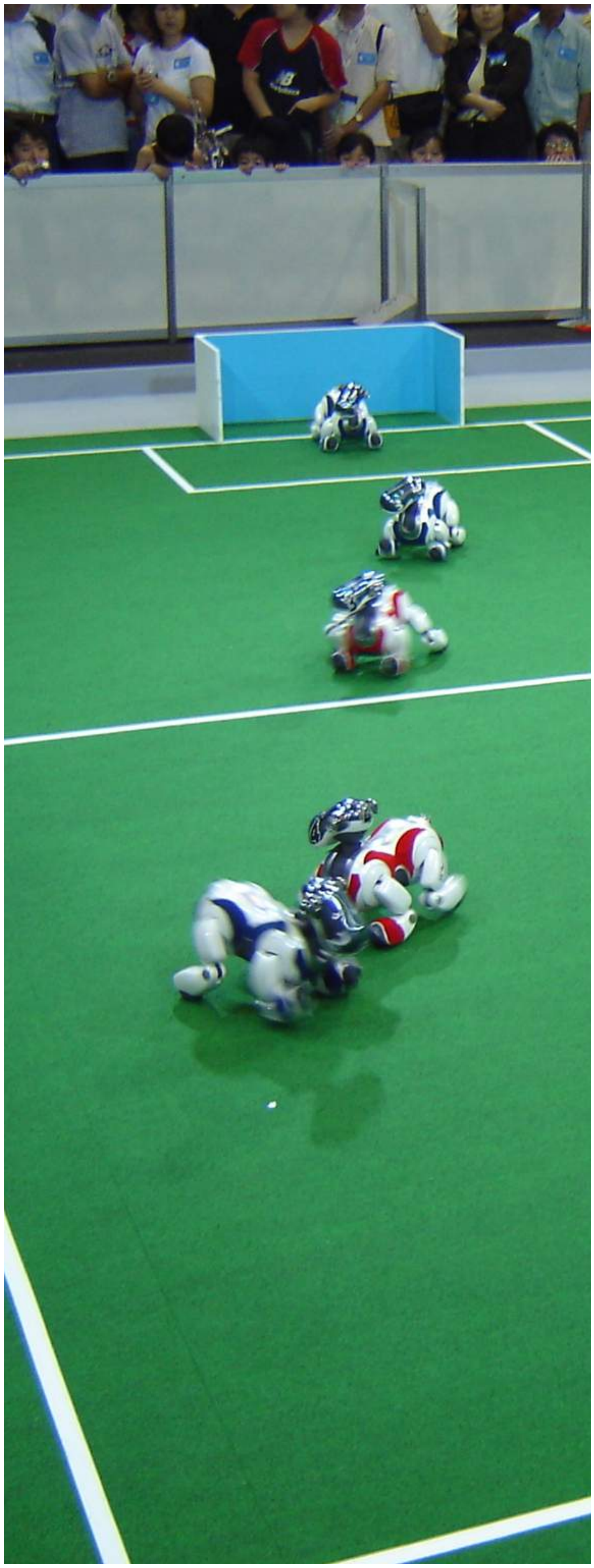
> **"SPORTS THEMSELVES ARE THE PINNACLES OF HUMAN PHYSICAL ACCOMPLISHMENT, AND FOR ROBOTICS THEY SERVE THE SAME PURPOSE: TO DEMONSTRATE THE ABILITY TO MANIPULATE OBJECTS WITH EXTRAORDINARY LEVELS OF CONTROL AND ABILITY."**

Interestingly enough, the robot created by the finalists of the 2014 RoboCup possessed an uncanny ability to return to a standing position after falling. They greatly resembled the motion of a human standing from a squatting position. Although the competition between robots in the RoboCup does not come anywhere close to matching the level of expertise in modern professional soccer, the progress being made is certainly promising. The ability of the robots to communicate with each other has greatly improved over the years as well. The robots in the competitions are not remotely controlled in any way, but are actually communicating through a router and pass information amongst themselves on the proximity of the ball, the fastest route to the goal, and even on potential defensive strategies.

Although it will take some time for the skill of the RoboCup robots to compete with their human counterparts, training aids for human participants have greatly evolved over the years. The soccer goalie robot mentioned previously is a

simpler training aid in that it only responds in a single plane of motion. Researchers from Kobe, Japan have expanded on this concept by developing a "multi-modal cave environment with suspended ropes that responds to physical stimuli in three-dimensional space."[3] The apparatus is able to track the user with a specialized motion-tracking system. The ropes are suspended above and connected to a racquet to return the tennis ball to the human opponent. The algorithm employed by this device is able to conduct collision detection in real-time, and this device has been tested and proven to function properly according to the researchers involved. Advances in robotics such as this will provide athletes with novel ways to improve their physical abilities without necessarily requiring the participation of another human opponent. This could result in benefits for athletes of all types and backgrounds, from amateurs to professionals.

Researchers and engineers are pushing boundaries every day as they try to make mechanical structures accomplish tasks that mimic human flexibility, speed and movement. They attempt to match the continual improvement of human athletic achievement with the mechanical movements of their robots. There have been great strides made as robotic tools for training have increased over the past couple of decades. Robots can prove to be of great assistance in pushing human athletes to new heights by becoming effective tools with which to train. At the same time, as artificial intelligence breaks new ground, robots may one day reach a level high enough to actually compete with human athletes.



INSIGHT INTO THE FUTURE OF BIONICS

John Palmieri

With the exponential growth in technology evidenced throughout the world, the importance of understanding exactly what is developing and progressing becomes increasingly pertinent to human life. Major developments in the fields of biomedical and electrical engineering are becoming a daily occurrence, and, as time progresses, researchers collaborating on a global scale are approaching their ambitious goals. Within the next decade, innovation and access to technology will produce devices with therapeutic applications that will revolutionize the medical industry. Therefore, the subject of biomimetic robotics is an important development in today's globalized society. By mimicking the natural function of the human body and employing novel methods to treat those with infirmities, biomimetic robotics can replace or enhance the natural abilities of the human body. Individuals who once had little hope of living to see their impairments alleviated may soon regain their lost abilities via biomimetic robots.

The bionic ear is an example of a major development in biomimetic robotics. The bionic ear can be directly implanted into the middle ear region, as opposed to the cochlear implant of the

conventional hearing aid. The middle ear, the region in which noise signals are amplified, consists of three bones, known as the ossicles. This region is primarily the site at which signal amplification occurs before mechanical vibrations of the middle ear region trigger the electrical stimulation of the auditory nerve, and consequently produce the physiological event that we refer to as hearing.[1] The bionic ear is a system that is primarily composed of an amplifier and a mechanical transducer that imitate the appearance and function of the middle ear region. The mechanical transducer first converts acoustic energy from incoming sound waves to electrical

energy. This change in electrical properties delivers a detectable signal to the amplifier, which intensifies the strength of the signal so that the auditory nerves fire and generate the perception of hearing. Without the amplifier, the output current of the bionic ear would not be prominent enough to trigger any sense of hearing from the auditory cortex of the brain. For those with hearing loss, this biomimetic replacement reestablishes the link between the external environment and the auditory cortex of the brain that is crucial for hearing. However, the bionic ear is not the only example of the therapeutic applications of biomimetic robots.[1]

> The therapeutic applications in this area of biomimetic robotics can improve the lives of those suffering from debilitating conditions: new opportunities become available and life acquires an entirely new meaning.

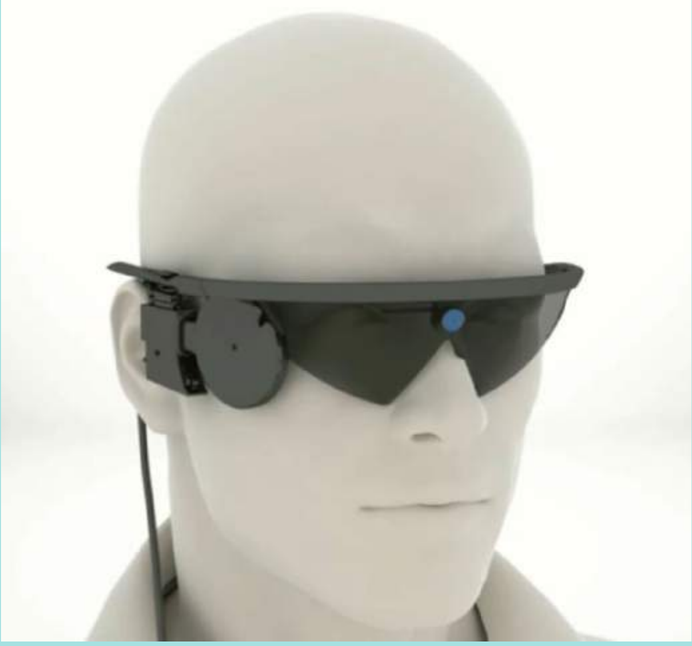
Another recent development in the field is the bionic eye. This device is capable of restoring sight for those with a vision impairment no matter how severe. As a symbol of progress in modern robotics, the bionic eye is capable of directly stimulating both the retinal and optical nerves. One version of the bionic eye involves a subretinal camera that is implanted into the back of the eye. This structure collects incoming light through the pupil and transduces the light energy from the local environment into electrical energy. The electrical energy can then stimulate the optical nerve and generate the sense of sight. However, this design is bulky and often results in complications due to the body's natural immune response to the presence of a large electronic device implanted directly in the body.[2]

Other versions of the bionic eye involve goggles that are worn externally that can send images of the user's surroundings to a photodiode implanted into the eyes.[3] After transducing the light energy signals from the environment into electrical energy, this photodiode is capable of sending a unidirectional current to the optic nerve. However, the images viewed by the patient with this device are often not clear. The complex biological functioning of the human body is still more advanced than modern efforts in biomimetic robotics. The bionic eye can restore low-quality vision to some extent, but it currently is not capable of perfectly mimicking the complex mechanisms of image processing and sensory input analysis.[3]

Though the medical outcomes of the bionic eye and ear seem inherently beneficial, there are some ethical issues that may be involved in the development and production of such products. Primarily, due to wealth disparity around the world, only wealthy individuals may be able to afford these expensive biomimetic robotics and therapeutic applications. Therefore, those who need urgent treatment may be denied access to what could potentially enhance the quality of their lives. Nevertheless, if this disparity is overcome, the positive results of these recent developments in bionics will certainly outweigh the negative. The benefits of hearing loved ones and associating efficiently with friends and coworkers is an invaluable experience that is being introduced to those who have little to no hearing. Regarding the development of the bionic eye, the implications of restoring eyesight are clearly profound and invaluable. Restoring vision to those who are blind or have poor eyesight is an unfathomable improvement to a patient's life. Scientific progress always opens new doors, but it is the responsibility of society to ensure the ethical utilization of these new opportunities.[4]

The therapeutic applications in this area of biomimetic robotics can improve the lives of those suffering from debilitating conditions: new opportunities become available and life acquires an entirely new meaning. Since scientific progress is inevitable, future developments in bionics will fix any technological issues with these devices. The outcomes of bionic devices will ultimately be determined by how humans utilize them. As with any form of technology, people will need to conduct an ethical cost-benefit analysis before using the revolutionary devices.

Argus II Bionic Eye



At the 2014 World Cup soccer championship in Brazil, Juliano Pinto, a Brazilian athlete who lost the use of both of his legs after a spinal injury from a car accident, kicked a soccer ball using an exoskeleton controlled by his mind.[1] How did he do it? He used a brain computer interface (BCI), a communication channel between the human brain and a computer that uses pattern recognition methods to convert brain waves into control signals that drive the exoskeleton.[2] The physical design of the prosthesis or robot that will be controlled can vary. The true innovation in a BCI lies in developing a method for computers to decode the outgoing signals sent by the brain, telling voluntary muscles to contract or relax.

The human brain and spinal cord are composed of neurons, cells that receive and send signals in the form of action potentials to other neurons, muscle fibers, and target cells. Action potentials are electrochemical signals that travel through the axons of neurons. An axon is a long branch extending from a neuron, and usually transmits signals away from the neuron cell body. On the other hand, dendrites are shorter branches of a neuron that generally receive signals from surrounding neurons and carry it to the cell body. Astonishingly, each neuron can be connected with up to 10,000 other neurons at synapses, which are very tiny gaps where the end of one axon meets the dendrite or axon tip of another neuron. Because of this intricate interconnectivity, groups of neurons in the brain can "work together" to produce synchronized action potentials at characteristic frequencies.[3]

The commands telling voluntary muscles

to contract or relax originate in an area of the brain known as the primary motor cortex; in other words, the primary motor cortex controls the voluntary muscles. The "cortex" of the brain is its outermost layer and is made up of gray matter. Gray matter is composed of neuron cell bodies, the axons of which constitute the deeper layer of the cerebrum known as white matter. The primary motor cortex consists of large neurons which have axons that project into the spinal cord. The entire body is represented in the cerebral hemispheres of the primary motor cortex.[3]

Each thought you have, each nuance of consciousness you experience, and each decision to move comes down to a sum of action potentials in your brain. A brain computer interface records these signals and attempts to decode, and convert them into computer code. Thus, in a prosthesis that is controlled by a brain computer interface, the BCI acts to record and translate signals from the primary motor cortex into movement.[4]

"Each thought you have, each nuance of consciousness you experience, and each decision to move comes down to a sum of action potentials in your brain."

In order to translate signals produced by the brain into computer language, it is important to first determine how to record the brain's signals. One way to do this is electroencephalography (EEG), a process that involves the placement of electrodes on the scalp to record voltage differences; these voltage differences correlate with the activity of the neurons in the general area below the electrode. The advantage of EEG is that it is noninvasive, portable, and has an insignificant time delay between the transmission and recording of brain signals.[4] For these reasons, EEG is an ideal recording mechanism for brain-computer interfaces, and was therefore integrated into the robotic exoskeleton used by Juliano Pinto at the 2014 World Cup.[1]

An electroencephalograph is a graph of voltage vs. time at a particular point on the scalp. Events such as sensory stimuli can induce changes in the activity of different neurons, which are recorded by an EEG as changes in electric potential (voltage). These changes are generally called event-related potentials (ERPs). A raw (unprocessed) EEG signal can contain fluctuation patterns of many different frequencies, or "frequency bands;" some of these frequency bands have greater amplitude and power than others. The range of frequencies and the power of each frequency band in the signal depends on the location of the electrode on the scalp and the neuronal activity in that area. Low frequency bands generally result from and represent the joint activity of many neurons over a large area, whereas high frequency bands generally represent the neuronal activity of smaller areas of the cortex. When a wakeful person relaxes with their eyes closed, the EEG normally displays alpha waves, which have a characteristic frequency, amplitude, and power. Certain events can decrease the power of the ongoing alpha signal. For example, when a subject moves their fingers, the power of the alpha frequency band is decreased in the motor cortex. This decrease in power is called an "event related desynchronization (ERD)". It occurs because an event triggers a decrease in the synchrony of underlying neuronal populations; that is, the neurons whose activity produces the EEG signal stop generating action potentials in synchronization. In the case of finger movement or voluntary movement of a different muscle, neurons in the motor cortex stop generating action potentials in synchronization with the rest of the cortex. However, events can also increase the power of a certain frequency band by increasing the synchrony of neuronal populations. This is called an "event related synchronization (ERS)". The amplitude of oscillations in a given frequency band is proportional to the number of neurons synchronously generating action potentials at that frequency.[5]

Raw EEG signals contain a great deal of voltage fluctuations that do not reflect neuronal activity. These voltage fluctuations are called "noise." Noise can be produced by blood vessels, EEG equipment, and other sources unrelated to changes in neuronal activity. There are several ways in which undesired frequencies are processed so that they practically "disappear" from the signal. A special type of circuit called a band-pass filter can be incorporated into EEG equipment to weaken and decrease the amplitude of physiological and equipment noise. Another way to decrease the amplitude of random noise is to average the electroencephalographs produced by several trials of the same activity. Using a process called moving window averaging, the noise in a single electroencephalograph can be decreased by averaging the signal over small time windows. These techniques "smooth" out the signal and allow the relevant ERP to be clearly seen.[5]

Mind-controlled robotic exoskeletons utilize an interesting principle of brain activity: imagined motor movements activate similar areas of the brain that are activated when the actual movements are carried out. Motor imagery in the motor cortex causes ERDs to occur in some frequency bands and ERSs to occur in other frequency bands. These ERDs and ERSs can be recorded by the EEG-brain computer interface, digitized, and used to initiate robotic actions.[4]

Subjects using an EEG-BCI system wear an EEG cap with many electrodes that measure voltages on the scalp. Different electroencephalographs are recorded by electrodes in various locations. These are each analyzed in the "training phase." Eye movement is also tracked in 3 dimensions using electrooculography, so that objects can be located by the robot machinery. Electrooculograms accomplish this by graphing the change in electric potential that occurs across the eyes when they move, thereby tracking the position the eyes are focused on. For tetraplegics, or individuals with total or partial paralysis of all limbs, EEG-BCIs can also incorporate head tracking using electromyography, which increases the tracking accuracy of the robot.[4]

Before a mind-controlled robotic system can be used, the EEG-BCI system must first be "calibrated" to EEG patterns specific to the user. Additionally, each individual user must practice motor imagination so that the computer can obtain calibration data that it can correlate to robotic commands. This is called the "training" phase.[4]

During the training phase, subjects have to respond to audio-visual cues by imagining themselves completing the cued movements. For example, subjects may hear a voice command that says "left", while seeing a screen that flashes the first letter of the word "left" in their language. This might signal a subject to imagine moving the fingers of his or her left hand, without actually moving his or her eyes or limbs. Even if a subject is paralyzed, an amputee, or for whatever reason unable to move the limb in question, they still imagine moving the limb. For amputees, that means imagining moving a limb that is no longer there. The subject then repeats the training sequence several times, while EEG activity is recorded. After the session is completed, a pattern of motor imagery-triggered power changes in subject-specific frequency bands is identified. This "Common Spatial Pattern" (CSP) is specific to a particular subject and a particular motor imagination.[4]

"One of the challenges developers of EEG-BCI technologies are currently facing is getting the technology to function in dynamic, everyday situations where there are many external distractions that are not present in a laboratory setting."

Next, subjects go through a "feedback" stage in which they perform the motor imaginations practiced during the training stage and receive feedback on how well the EEG patterns they are producing conform to the pattern identified during training. Feedback can be in the form of a cursor whose movement speed is proportional to the correlation between the CSP identified in training and the EEG the subject is currently producing as he or she attempts to imagine performing the cued motor movement. In this way, subjects learn how to produce the same Common Spatial Pattern each time they imagine performing a particular movement.[4]

Finally, the subjects can use their individualized EEG-BCI to control a robotic system. This system could be a robotic arm capable of grasping objects.[6] Other possible functions that can be integrated in a robot include kicking, moving a cursor on a computer, and pushing a wheelchair. In the future, EEG-BCI-controlled robots can potentially help patients with spinal cord injuries, cerebro-vascular injuries, amputations, and progressive muscle wasting diseases such as amyotrophic lateral sclerosis (ALS), Duchene's muscular dystrophy, or spinal muscular atrophy. One of the challenges developers of EEG-BCI technologies are currently facing is getting the technology to function in dynamic, everyday situations where there are many external distractions that are not present in a laboratory setting.[4] However, EEG-BCIs still hold tremendous potential to allow people with restricted motor abilities to regain control over their daily lives. Juliano Pinto's 2014 World Cup kick off was an inspiring symbol of that potential.

PUTTING THE "AUTO" IN AUTONOMOUS

Saad Ali

Over the last decade, automobile manufacturers around the world have been pushing the boundary of what seems to be the "norm" in the cars that we drive today. Fuel efficiency has increased drastically in the last few years, with existing cars far surpassing the efficiencies of cars of the past.[1] The dreaded task of parallel parking has also been automated to make drivers' lives easier. More subtly, automated head lights and windshield wipers that turn on in the absence of light or in the presence of water have also been implemented in most cars that came out in 2014. With every development, cars are becoming progressively "smarter" as well as more interactive. Ford has manufactured "talking" cars for almost 5 years now, allowing the driver to do simple tasks such as changing the radio station via voice commands.[2] Now cars are beginning to come preinstalled with Siri[3] and Google Now[4], powered by Apple and Android, respectively. Each breakthrough seems to be focused on making something automated so that drivers can focus on the road and not distract themselves with the trivial. And yet, driving could become even safer with the self-driving car.

Google has been working on a project called "Google Chauffeur,"[5] software that can completely take over the driving of a car. Because this project is still very much in development, Google has been quite secretive about what makes Chauffeur function. What is known about Chauffeur is that it requires, not surprisingly, extensive data on the route to be travelled in order to function properly.[6] Although Chauffeur is still in its primitive stages, it is an innovation that can truly redefine the modern world. With Chauffeur in development, Google is taking steps towards making driving a painless task.

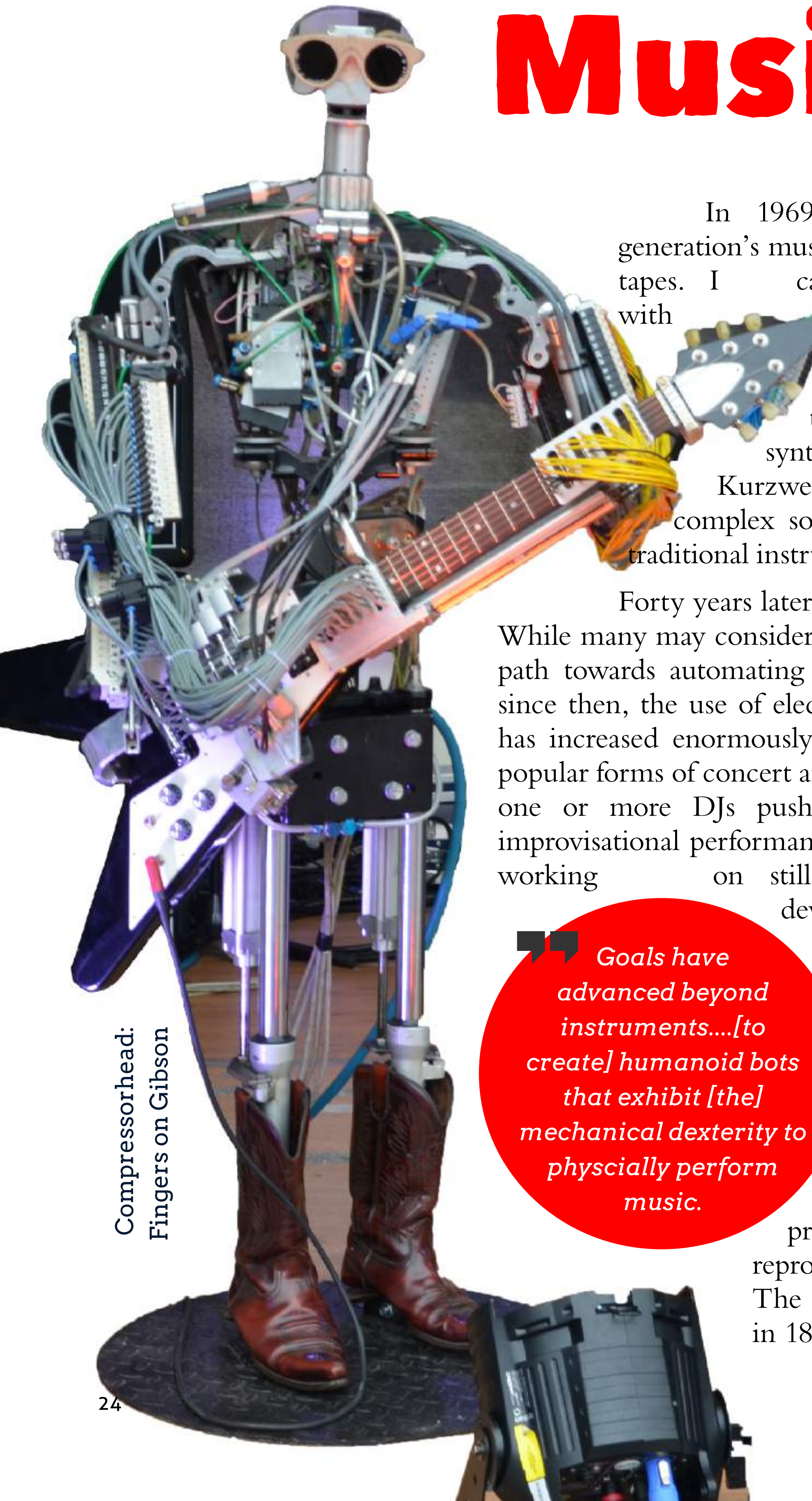
Chauffeur surely is a bold vision; however, Google must first deal with some very real limitations in the present in order to ensure its future success. Chauffeur requires too much data on a single route for it to be considered a practical means of travel for the average person.[6] In addition, Chauffeur cannot be used in adverse weather conditions such as snow, heavy rain, or hail.[6] Perhaps most concerning for Google is if Chauffeur is "too successful" it might lead to people not paying attention to the road at all, which could lead to even more accidents that Google set out to prevent. The program is not able to navigate through some special case circumstances such as construction work or recent potholes.[6] Still, Google is developing this technology to be somewhat autonomous. If a newly placed stop sign appears on the route for which Chauffeur has data, it will be able to recognize the sign as a stop sign and stop accordingly.[6] This is a product of Chauffeur having a multitude of sensors that detect everything from other cars and traffic signals to pedestrians and animals. With these sensors in play, self-driving cars could significantly reduce the amount of collisions, and therefore, lives lost, because the sensors are able to detect things that might go unnoticed by a driver.[7] If Chauffeur detects an upcoming situation with which it is unfamiliar or is not programmed to handle, it warns the driver of the obstruction to resume manual control so as not to cause an accident.[5] For this reason, there are rarely any instances of Chauffeur directly leading to car crashes.[5]

A drastic reduction in the amount of collisions is perhaps the greatest achievement and impact that Google Chauffeur could have on the automotive world. Humans are capable of making mistakes while driving because they can get distracted and lose focus on the road. With Chauffeur, however, the sensors and actions are coded programs that will always follow what has been coded for, thus eliminating human mistakes. Chauffeur may also prove to be extremely useful to the disabled.[7] For those who are vision impaired or disabled, one would only need to sit in the car and select the destination in order to get there. Although Google's Chauffeur software can prove to be quite beneficial for some, Google must first work out the issues in the software in order to bring the program to the mainstream market. Further development and integration of sensors to account for various obstacles, as well as improved autonomous decision making, are necessary for the self-driving car to become practical. With Google's continued efforts and determination in perfecting this project, the self-driving car could be available to the average person within 5 years.[5]

Google Self-Driving Car

ROBOTS in Music

By: Hari Rao



Compressorhead: Fingers on Gibson

In 1969, Jim Morrison said, “The new generation’s music …might rely heavily on electronics, tapes. I can kind of envision maybe one person with a lot of machines, tapes, and electronic setups.”[1] Morrison was inspired to make this statement in the 1960s due to the popularity of the synthesizer, an invention by Raymond Kurzweil that automated the creation of complex sounds that could not be created with traditional instruments alone.

Forty years later, Morrison’s prediction has come true. While many may consider the synthesizer as the first step on the path towards automating music production and performances, since then, the use of electronic machines in the musical world has increased enormously. On one hand, one of today’s most popular forms of concert are electronic music festivals that feature one or more DJs pushing buttons and turning knobs in improvisational performances. On the other hand, engineers are working on still further advances: they are now developing robots that can play instruments guided by sheet music.

> *Goals have advanced beyond instruments….[to create] humanoid bots that exhibit [the] mechanical dexterity to physcially perform music.*

When one learns how to play music, the traditional approach is to use sheet music and learn the technical aspects required to play a piece. The evolution of robots in music followed a similar path; initial innovations for automating music production were engineered to reproduce music exactly as it was written. The player piano, initially developed back in 1880, is a well-known device that can be

Compressorhead: Stickboy

seen in various public places such as hotels or shopping malls. It is a self-playing piano that plays pre-programmed tunes in a seemingly magical way that requires no human counterpart; the keys move of their own accord, playing the correct notes at the correct times. Originally, these pianos contained "a pneumatic or electro-mechanical mechanism that operates the piano action via pre-programmed music recorded on perforated paper."[2] Modern implementations use MIDI files stored on digital media.

Now goals have advanced beyond instruments that can generate pre-determined sounds. Many robotics laboratories have been working on developing humanoid robots that exhibit enough mechanical dexterity to physically perform music. Progress has been made in this area to the extent that robots can now play instruments requiring multi-faceted skills. For instance, researchers at Waseda University in Japan have developed a robot they call WAS-2[3] that is able to play the alto saxophone. This robot is able to replicate human-like skills, combining the dexterity of finger movements and providing variable input of air through an apparatus functioning similarly to the human mouth.

The next reasonable goal is then to attempt to coordinate many humanoid robots to perform a single piece of music together – like the robotic metal band, Compressorhead.[4] There is a YouTube channel where you can watch videos of them demonstrating their ability to move to the rhythm of the music and play various classic rock and metal songs for live audiences. The robot guitarist has enough digital fingers to span the entire guitar fingerboard, while the drummer has four arms. These two appear to take liberties with the definition of "humanoid" robots, seeing how they differ in both appearance and construction. Appearances aside, they are able to perform exact replicas of pieces by various musical artists. The impressive

Player Piano

accuracy of Compressorhead's renditions of musical pieces represents both the strength and the downside of their performances.

The aspect of music which makes it meaningful and real is the improvisation and "soul" involved in a musical performance. Improvisation seems to be one of the hallmarks of what makes music human. The ability of a performer to deviate from the original composition, yet still encapsulate the intended ambience of the song can evoke an intense emotional response from active listeners. Enabling robots to mimic this seemingly exclusively human ability of improvisation is a huge challenge. It may take a few more years for robots to even come close to accomplishing this feat.

Nonetheless, it is exciting to see how far technology has evolved in order to mimic natural human behaviors. As curious innovators, human engineers will take every avenue possible to explore new depths of advancing artificial intelligence. Futurist and Inventor Ray Kurzweil has said, "Sometimes people think that emotion and art are sort of sideshows to human intelligence… things like being funny, or expressing a sentiment, maybe in a poem or in a musical piece. That's the cutting edge of human intelligence."[5] To reproduce this aspect of human intelligence in the creation of music, thus, seems to be the next logical step for the evolution of robots in music.

DRUG SNIFFING ROBOTS

ABHISHEK TRIVEDI

Underwater robot developed by researchers at MIT

Although many citizens do not see the drug trade occurring undercover around them or its adverse effects, it is actually at an all-time high. The Drug Enforcement Agency (DEA) is trying its best to curb this problem by stationing over 4,400 officers throughout the country, and making about 30,000 arrests each year for the sale and distribution of narcotics.[1] Despite these security measures, drug trafficking is still an ever-growing problem. However, law enforcement now has a new weapon in the making to target the center of the problem. According to the U.S. Drug Enforcement Agency, more than 90,000 ships dock at U.S. ports per year. These ships contain over 400 million tons of cargo in 9 million shipping containers. In addition, several thousand smaller vessels visit the many coastal towns in the country.[4] It is amidst this busy traffic that drug traffickers are able to conceal and distribute contraband throughout the United States. To fight this issue, engineers at MIT developed an underwater robot that can detect what is inside incoming ships to check if drugs are being hidden in places such as fake hulls or propeller shafts.[2]

The robot itself is actually smaller than a football, but this makes it all the stealthier. While generally oval shaped, one side of it was designed flat so that it can perform ultrasound scans of a ship while sliding along the bottom of the vessel. Further, a waterproof exterior keeps the electrical parts within safe from water damage. The electrical components include a rechargeable lithium-ion battery, that currently has a battery life of over 40 minutes, but researchers are confident that they can increase the battery life to 100 minutes. One of the best features of the robot is its stealth; it is nearly impossible for smugglers to detect this robot because the waves created by its propulsion system are minimal, making this the perfect underwater patroller.

This 'drug sniffing' underwater robot could be revolutionary, not just for law enforcement, but also for the future of robotics. As the robot's co-designer Sampriti Bhattacharyya explains, "It's very expensive for port security to use traditional robots for every small boat coming into the port… If this is cheap enough — if I can get this out for $600, say — why not just have 20 of them doing collaborative inspection? And if it breaks, it's not a big deal. It's very easy to make."[3] The low cost is possible because parts were made using 3D printing technology. Further, this robot can also be used in other applications. As Nathan Betcher, an officer in the U.S. Air Force, pointed out, military officials could use this device for a range of underwater operations. These include finding stress fractures in ships that need repair or simply speeding up regular maritime traffic.[3] Because this robot is still in its primary testing phase, its potential has just been touched. It could truly be a groundbreaking weapon in the fight against drugs.

BAXTER, THE INDUSTRIAL ROBOT

SAHITYA ALLAM

Employees of production lines across the country may have noticed a new worker on site recently. At six feet tall and three hundred pounds, with a bright red exterior and a pair of comic eyes, Baxter the industrial robot definitely stands out from the crowd. However, it still has a distinct, “human-like” quality that has enabled it to seamlessly integrate into the production operations of several manufacturing companies. The robot picks up plastic components, performs a task, looks around worriedly for validation if it makes a mistake, and then moves on to the next task.[1]

Baxter the robot at work at ReThink Robotics' headquarters in Boston

Amazingly, Baxter can be taught tasks very easily, almost as easily as a human. Chris Budnick, president of Vanguard Plastics, a company that allowed one of the first prototypes of Baxter to be tested in its production facilities, claimed that it only takes a matter of minutes to program Baxter. “Almost anyone, literally, can in very short order be shown how to program it,” says Budnick.[1]

Baxter is the first in a generation of smarter, more adaptive industrial robots that are simple to program and handle deviations in their environment with remarkable poise. Unlike industrial robots of previous decades, Baxter can easily work around a toppled chair or shifted table due to its sophisticated computer vision software.[1] It is believed to be so safe that it very rarely, if ever, presents harm to human coworkers. With such technological advancement, robotics and automation may finally make an impact on job and industry growth in the United States. Although having a Baxter robot aid in production may worsen job prospects for low-skilled, blue-collar workers, it could allow the United States to compete against foreign nations offering low-wage labor by taking over the menial tasks that manufacturers usually assign to these workers.[2]

The key to Baxter’s facilitated

Rethink Robotics Employee teaches Baxter how to complete a task

programmability is its ability to quickly recognize and register objects. To teach Baxter to recognize something, one only needs to hold the object in front of one of Baxter's cameras, located in the head, chest, and ends of each arm.[3] To program an action, one can move one of Baxter's arms through the desired motion and select from a range of preprogrammed actions using a set of dial controls in each forearm.[3] Moving Baxter's arms is not a difficult task either; even though Baxter weighs 300 pounds, its arms are very light because its motors are activated in response to touch, making the limb easy to move despite its weight. [1]

Furthermore, Baxter does not need to be isolated from other workers when performing a task - one of its most useful qualities. If someone were to put his or her head in the way of Baxter's arm, he or she would only receive a small bump. Baxter moves slowly and gently, but not to the extent that tasks cannot be performed with greater efficiency than if a human were to perform them. Baxter is also equipped to sense human movement with an array of sonar sensors positioned around its head. When the sensors detect an unexpected change in force nearby, Baxter immediately stops to avoid making an impact.[3] In the next few years, Baxter and other smart, industrial robots are likely to revolutionize the manufacturing industry. The cost-competitiveness and adaptability of the Baxter robot is unparalleled by any other option available to handle low volume, high-mix production jobs.[2] Baxter will provide a new dynamic to the worker base and improve efficiency while easily integrating into the existing production framework.

Paro-Peutic Happiness

Sahaana Uma

Animal-assisted therapy has been used for many years now to improve patients' social, emotional, and cognitive function by training domesticated animals to provide assistance and comfort to people. Recently, scientists have started to use this concept to develop robotic therapy animals. In 1993, Dr. Takanori Shibata, a researcher at Japan's National institute of Advanced Industrial Science and Technology, designed the Paro robot. Paro is a therapeutic robot that is modeled after a baby harp seal and displays emotional responses in order to stimulate positive effects on hospital patients.

Paro is 57 cm long and weighs 2.7 kg, approximately the same as a newborn baby. Its anti-bacterial and soil resistant artificial fur can be either white or gold. The robot has strong internal robotics that can handle long-term use and an electromagnetic shield, which makes it safe for pacemakers. It is powered by an internal rechargeable battery that uses a cable designed to look like a pacifier for whenever Paro is "hungry."[3]

The engineers tried to imitate a real baby seal and designed it to be active during the day and to sleep at night. Paro has sensors that give it the ability to recognize light and dark. It understands when it is being held or stroked and can recognize its name, greetings, and compliments. It is even capable of remembering specific interactions. Paro expresses itself by moving its flippers and head, creating emotional facial expressions with blinking eyes, and mimicking the noises of a real baby seal.[5] From crying for attention to squealing when stroked, it behaves just like a real, lovable pet and has the capability to instantly brighten the moods of patients.

Paro uses multiple different kinds of sensors and artificial intelligence software that help it function. The five types of sensors in place react to touch, light, noise, temperature, and posture. These sensors

Japan's National Institute of Advanced Industrial Science and Technology where Dr. Takanori designed the Paro robot in 1993.

monitor and detect changes in the sounds, light, temperature, position and touch, enabling Paro to respond the way it does to human interaction.

Paro is designed to have a positive psychological effect on people who interact with it. Since it enjoys being stroked and dislikes being hit, it acts in a way that allows it to be stroked and gradually learn to develop a personality that its owner likes. Elderly people with dementia may get agitated and upset easily and Paro can help these patients settle down and improve their moods. The robot has displayed promising results after being tested with senior citizens in nursing homes and with autistic children.

There are many advantages to implementing robotic therapy in place of traditional animal-assisted therapy. Robotic animals like Paro have positive effects on mental health. Research conducted at nursing homes has shown that patients' stress levels decrease as a result of the therapy. [2] Robotic animals are also much safer than domesticated animals because they can be controlled, ensuring that the animal does not harm the patient. However, there are also some disadvantages to using this robotic animal for therapy over traditional methods. First, Paro robot is estimated to cost between $2500 and $3000, which can be very expensive for both the patients and therapy centers. [6] It also has the potential to fail, which can cause trauma to a patient. These factors need to be carefully considered before employing any robotic animal-assisted therapy.

Researchers are continuing to work on perfecting the designs and analyzing the effects of Paro by conducting user studies. Currently, there are 1300 Paro robots in use in Japan. European countries such as Denmark have introduced it as well, and it has been FDA approved in the United States. However, Paro is not the only therapeutic robot on the market; Popchilla and Keepon are names of other stuffed-toy robots for children with social developmental disorders such as Autism.[1][4] By the progress achieved in the past few years with robotic animal therapy, this could be the future for children and adults with disabilities.

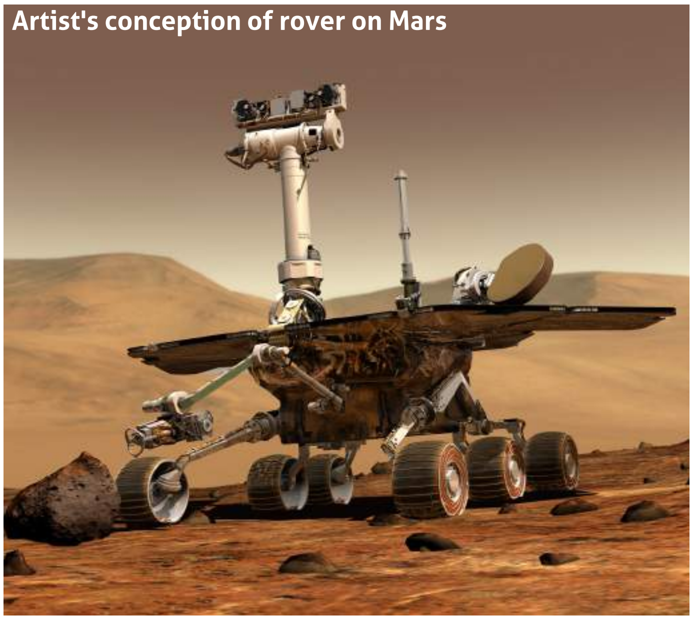
Space Robotics

Chaitali Gandhi

Robotics, a widely growing field, is making influential headway in the realm of outer space. For instance, the company, Tethers Unlimited, is developing a more efficient method that will enable orbiting objects such as satellites to be built in space.[1] Normally, these structures must be constructed on Earth before they are brought to space; however, Tethers Unlimited is planning on building a robot, SpiderFab, which will use its multiple limbs to actually construct parts of these structures in space. In the field of space robotics, the objective is to develop machines conducive to the space atmosphere that can perform advanced tasks in place of astronauts. Due to the inherent dangers in space, the use of robots is a better alternative to sending astronauts on space missions. Further benefits of utilizing robots include cost and time efficiency in the long run. The Mars Exploration Rovers and the Robonaut are perfect examples that portray the many innovations behind space robotics.

The Mars Exploration Rovers, Opportunity and Spirit, were designed to conduct a ninety day investigation in 2003. Fast forward twelve years and Opportunity is still active, while Spirit remained in operation for six years. The purpose of this particular mission was to investigate rocks and soil to understand water activity on Mars.[2] In order to perform successfully, all rovers must possess several components to support their different functions. There is an external structure to protect its internal system, a computer to process information, and methods of temperature control, including heaters and insulation.[3] In addition, there is a mast for the cameras to provide a human scale view, arms to extend its reach, wheels for mobility, antennas for modes of communication,

Steve Robinson on Canada Arm


Artist's conception of rover on Mars

and batteries and solar panels for sustainability. Specifically, Opportunity and Spirit each contain six wheels that are mounted to a suspension system, guaranteeing that the rovers stay on the ground regardless of the terrain. Each wheel is about ten inches in diameter and contains shock absorbent spokes. The success of the rover's mobility system revolves around the rocker-bogie design that "allows the rover to go over obstacles or through holes that are more than a wheel diameter in size".[2] One of the most innovative technologies that these rovers have is more autonomy compared to others in the past. They are able to navigate themselves and choose their own particular routes to reach destinations as well as avoid obstacles in their path; these abilities enable longer daily drives. A newer technology, the Robonaut, is an incredibly innovative step in space robotics. It is a "dexterous humanoid robot" whose job is to assist, and in some cases, replace astronauts.[4] Ideally, it should function as an astronaut equivalent. Presently, there are four existing Robonauts with several others in development.

"The objective is to develop machines conducive to the space atmosphere that can perform advanced tasks in place of astronauts."

The innovative technology of the Robonaut lies in the agility of its hands, arms, head, and body.[5] The Robonaut Hand is the "first under development for space EVA [extravehicular activity] use and the closest in size and capability to a suited astronaut's hand."[5] Each consists of a forearm, wrist, hand, and fingers. The forearm, which is four inches in diameter and eight inches long, accommodates fourteen motors, twelve circuit boards, drive electronics, and the wiring for the hand. The actual hand is made up of two sections involving a dexterous work set and a grasping set. The former is used for manipulation whereas the latter is for a stable grip. The fingers, shock mounted into the palm, are used in different combinations to create the dexterous work set and grasping set. When all of these elements are synchronized, the Robonaut Hand will be capable of executing different actions and using the required tools. The Robonaut's arms have strength and reach comparable to human arms, in addition to fine motion, redundancy, safety, thermal endurance, and range of motion greater than that of a human limb. In order for this to be possible, lubricants, strain gages, encoders, and angular position sensors are being custom designed. The body of the Robonaut is an aluminum endoskeleton that is covered by a protective outer shell and it serves to protect in several ways. Primarily, it hides the delicate components containing electronics and wires. The padded jacket and a floating suspension also cushion any sustained impact. The head of the robot is still being developed; however, currently, it has an articulated neck that enables the tele-operator to control the view of the camera, simulating the astronaut's eyes. The helmeted camera is a unique design; typically, in robotics, the camera is exposed.[5] Due to the Robonaut's objective of working alongside astronauts in space, a better protective system was necessary.

Mobility is a crucial and tricky aspect of an advanced technology such as Robonaut. The robot must be able to travel to several worksites while performing meaningful tasks. Platform, motors, electronic components, and supplies must be carefully chosen to establish successful mobility. Thus, different systems are being tested to determine which is the most appropriate. To date, Centaur, Zero-G Leg, and Robotic Mobility Platform (RMP) are part of the mobility systems. Centaur is a four-wheeled platform that is made to travel over rough terrain. It allows Robonaut to explore, gather samples, and assist. Zero-G Leg is a stabilizing leg that allows Robonaut to assist astronauts. When attached between the robot and the astronaut, Robonaut can climb and use similar gear to that of a human astronaut. Zero-G Leg also senses and controls interaction forces. Finally, RMP is a two-wheeled vehicle. It is able to balance and maintain position while simultaneously driving and turning.[6]

Space related robotic technology is an advancing and growing field. Despite the progress in this domain, many limitations remain. Funding for robotics research is expensive; acquiring a continuous endowment to proceed is also a constant strain. Further, even though robotic technology is reaching human mobility and dexterity, it has not yet reached the same level of reasoning. Despite these limitations, however, robots still offer a viable alternative in situations where traveling to unsafe and extreme environments is required. Because of this, the trek to cutting edge technology within space robotics must be continued.

ROBOTIC SURGERY: A VIABLE OPTION?

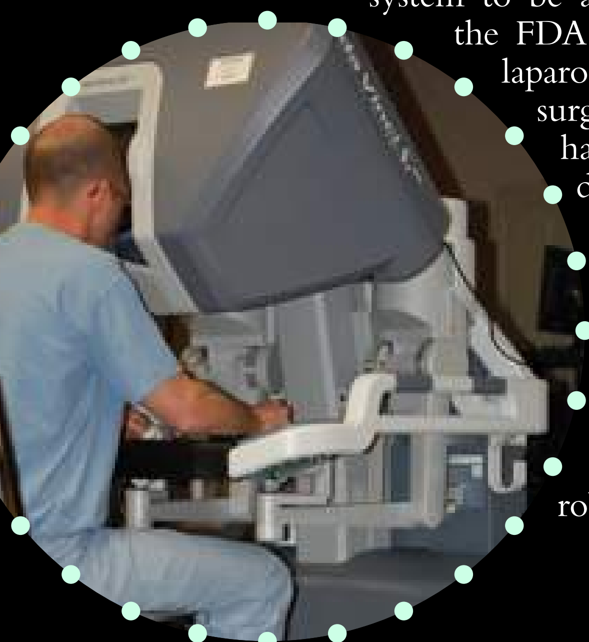
Kaila Trawitzki

The inevitable happens; accidents occur and surgery is often necessary at some point in one's life. However, surgery can be risky and followed by long periods of recovery. Surgical robotics is, thus, an emerging field which is trying to meet the need for reliable, minimally invasive procedures.[3] Typically, in robotic surgery, a surgeon uses miniaturized surgical instruments that he or she controls through a console located in the operating room to perform the surgery. The advantage is that these robotic instruments generally require no more than quarter-inch incisions to operate. In 2013, robots were used in 422,000 surgeries in the US, which is 15% more than the year before. Robotic surgery has greatly advanced over the last 30 years, but more research is necessary to fully develop and utilize this technology.

The Da Vinci surgical machine may be the most well-known robotic surgery equipment. Engines on the framework move the automated arms and instruments, following the specialist's hand movements on the controls. The machine subsequently supplies critical mechanical feedback to the hands of the specialist, providing an input that simulates the real feeling of touch and adds to the improved visualization allowed by the 3-D perspective. By manipulating the master controls using his or her fingers, primarily in a pincer-like movement, the surgeon can operate all the arms of the robot simultaneously. This is combined with visuals through a stereoscopic high-definition monitor that give a highly detailed 3-D view of the operating site, virtually placing the specialist inside the patient. Every movement the surgeon makes from the master controls is replicated precisely by the robot. When necessary, the surgeon can even change the scale of the robot's movements: for example, if he selects a three-to-one scale, the tip of the robot's arm will move just one inch for every three inches the surgeon's hand moves. And, because of the console's design, the surgeon's eyes and hands are always perfectly aligned with his view of the surgical site, minimizing surgeon fatigue.

Despite futuristic connotations, robotic surgery has quietly existed since the 1980s. In 1985, the PUMA 560 robotic surgical arm successfully completed a delicate neurosurgical biopsy. This marked the first documented robot-assisted surgery. Two years later, the first laparoscopic procedure, surgically removing a gallbladder, was performed using this robotic system. Then in 1988, PUMA was used to perform transurethral resection, which both diagnoses and treats bladder cancer.[1] Later in the 1990s, Computer Motion's AESOP system, the first robot approved by the Food and Drug Administration (FDA), assisted in endoscopic surgery with reduced body cavity invasion. During a minimally invasive procedure, the surgeons would create several tiny incisions in the patient's skin. An endoscope, a long, thin tube with a miniature camera attached at the end, is passed through one of the incisions. Images from the endoscope are projected onto monitors in the operating room in order for surgeons to obtain a projected and precise view of the surgical area. Special instruments are passed through the other openings.

However, it was not until 2000 that the operating room became acquainted with modern robotic surgery. The Da Vinci Surgical System was the first robotic system to be approved by the FDA for general laparoscopic surgery, and it has dominated the field of robot-assisted surgery ever since. This advanced machine led the evolution of the robotic surgical field from the simple arm of the PUMA 560 into an all-encompassing system comprising assorted surgical instruments, such as cameras and scopic devices. Using a 3D magnification screen, the human surgeon is able to view the operative area with high-resolution clarity.[4]

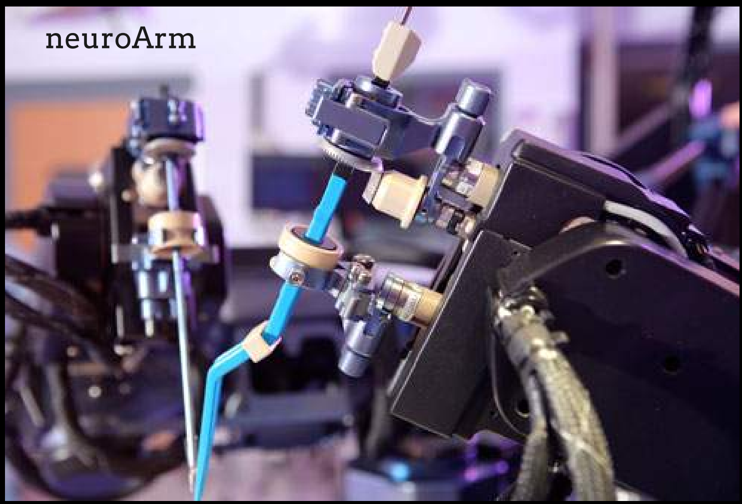


Consequently, the robotic surgical field has significantly evolved. For example, while the PUMA's single arm was a bulky chunk of 1980s robotic technology, the Da Vinci offers four slender surgical arms, each just one centimeter in diameter. By minimizing the amount of contact time between instrument and interior tissue, the Da Vinci ensures lower risk of infection. Due to this fact, the miniaturization of the surgical instruments was heralded as a breakthrough in minimally invasive surgery.[4] Meanwhile, a feature known as EndoWrist® was designed to replicate the skilled movements of the surgeon, who would operate the machine remotely using a set of controls.

Approaching the contemporary age of medical research and innovations, robotic surgery has had unprecedented developments. Currently, the future of robotic surgery lies within a subset known as microsurgery.[3] However, microsurgery, defined as intricate surgery performed using miniaturized instruments and a microscope, will not replace traditional surgeries, but could help solve specific problems presented over years of surgical operations. One example is the treatment of breast cancer patients, who often suffer severe swelling and pain in their arms and hands following the removal of lymph nodes. This condition, called lymphedema, is caused by the disruption of natural drainage channels, indicating improper blood circulation in the patient's system. Redirecting blood flow is possible but incredibly challenging, as surgeons try to sew tiny vessels that are barely visible under a microscope. The neuroArm, a robot that can perform microscale neurosurgery while a patient is undergoing a magnetic resonance imaging (MRI) scan, has already been used in Canada to remove a 21-year-old patient's brain tumor. The robot, which uses non-ferrous materials to avoid interacting with the MRI machine's magnets, was designed by the surgical imaging firm IMRIS, and has since been rebranded as the SYMBIS Surgical System. SYMBIS is not available for sale yet, but IMRIS already sells specialized MRI systems that allow scans to be performed mid-procedure. Once it is cleared for use, SYMBIS will allow surgeons to image the patient's brain without the use of nearly as many instruments.[4]

Furthermore, a fist-sized robot capable of responding to abdominal emergencies in outer space such as a ruptured appendix or perforated gastric ulcer has been developed by Virtual Incision in Lincoln, Nebraska.[2] The robot is capable of operating by sliding into the body through a careful incision and operating inside the abdominal cavity, which is filled with inert gas to create room. However, differences in gravitational acceleration between space and earth continue to create difficulties in the development of surgical robots for use in outer space. Therefore, Virtual Incision has been working on its design for a few years to overcome the environmental limitations. The latest version weighs a mere 0.4 kilograms, and has two arms loaded with tools to grab, cauterize and suture tissue. Currently, the video feed of the patient relays to a control station where a human surgeon operates it using joysticks.[3]

Although robots would be more useful if they could operate autonomously, current robotic surgical technology still signifies a step in the right direction. There remains a limit as to what tired human hands can accomplish, which is why assisted robotic surgery alone may maintain a distinct advantage over weary, exhausted surgeons. For the patient, there is usually less blood loss, a shorter hospital stay and less reliance on postoperative pain medication. The cosmetic benefit of decreased scarring also remains a viable advantage. However, reports of robotic risk are on the rise, highlighting the growing need for ergonomic improvements.[2] Therefore, in order for more significant medical process, safe and practical therapies must be utilized involving microscopic view and manipulation. These advances will need to be rigorously validated not only through patient outcomes, but also through cost efficiency. Eventually, robotic surgery may well become a normal mainstream procedure.



Brain

CONTROLLING EXTERNAL DEVICES...

The ability of the brain - the most amazing organ in the body - to control thought and movement has been the nucleus of many works of science fiction. Similarly, the idea of a brain-to-computer interface (BCI) has remained in Sci-fi for decades. That is until the BrainGate project began - a project aimed at creating a BCI that would enable the user to control a device with their mind.[3] BrainGate was developed by the partnership of Cyberkinetics, a biotechnology company, and the Department of Neuroscience at Brown University. The BrainGate project is focused on quadriplegics and its goal is to re-empower quadriplegics with some, if not all, basic functions by providing them with devices they can control with their mind alone.[1]

The idea was to have a device that receives data from the brain, specifically the primary motor cortex that is responsible for our voluntary motion, and feed that data to a device that will convert that signal to an action in the device. The teams decided that a direct BCI was required. This means that they implant a chip smaller than a dime with electrodes thinner than a human hair into the brain's motor cortex. The implant is then connected to an external device that processes the data and sends that data to the actual device that they want the patient to control. The BrainGate project has produced two successful BCI devices: a computer and a robotic arm.

The process begins when the 4 mm chip comes into contact with the brain and the electrical signals in the brain are detected by the chip. The chip is attached to a connector, the component responsible for propagating the electrical signals from the chip to the converter. The converter then attaches to the computer that has two distinct functions; to provide information about the signal patterns that researchers can use to determine which portions of the signal actually contain the command to control the device; and to input the signal into it, resulting in a motion in the device.[2]

The BrainGate's system is the first interface to actually convert electrical impulses in the brain into complex, non-predetermined motions; in other words, it does not function with an on or off button, but rather actively understands what you are trying to do. BrainGate actually translates the impulses created for a specific motion into digital data. The BrainGate developers are currently trying to make the device wireless, so there is no need to plug the device directly into the brain.

BrainGate underwent several trials on animals before the first human tests on Matt Nagle and Cathy Hutchinson. The BrainGate team placed the device on a disabled rat's motor cortex and placed food within the rat's vision but out of the rat's reach. The experiment harnessed the rat's desire to eat the food to induce the rat to learn how to send out the specific electrical signals needed to automatically move the food closer. After sufficient testing on rats with promising results, testing was performed on monkeys at the University of Pittsburgh.[5] The monkeys were given a more difficult task of using their minds to move a robot arm with a banana close enough to eat. Their drive for the banana allowed the monkeys to adapt to the system, eventually moving the arm close enough to eat the banana.

BrainGate in humans started with a brain to CPU interface in which the user's mind could control a cursor on a computer monitor, click icons, and eventually type emails, a task that requires great precision and accuracy.[5] Once researchers understood that the BrainGate device does not guess like other devices that claim to "read the mind" but actually converts the desired brain signal into desired motions, the team began expanding their research into the 3D world involving robots that move in the xyz planes.[3]

The results from the collaborative study can be eventually applied on a much larger spectrum. Imagine surfing the web with your thoughts or driving a car with your mind, perhaps even playing a virtual reality game in which you control the character without lifting a finger, literally. On an even larger scale, imagine a home in which everything, from the lights to the appliances, are activated by thought. BrainGate may be the 21st century equivalent to the invention of the light bulb in the sense that it is the beginning of a technology that has the potential to change the way people interact with everyday objects.

BrainGate is far from a perfect device and it is still undergoing testing. Current difficulties include: decoding the brain signals, isolating the desired signals while preserving their quality, and maintaining cost efficiency because it is very expensive to develop both the hardware and software.[3] However, these obstacles are small when compared with the smile Cathy had after she fed herself coffee after 15 years of relying on her personal care taker.

gate:

WITH YOUR MIND

BY: AMIN GOLAMY-SADIG

An Unlikely Pair : Robotics and Chemistry

Monica Torralba

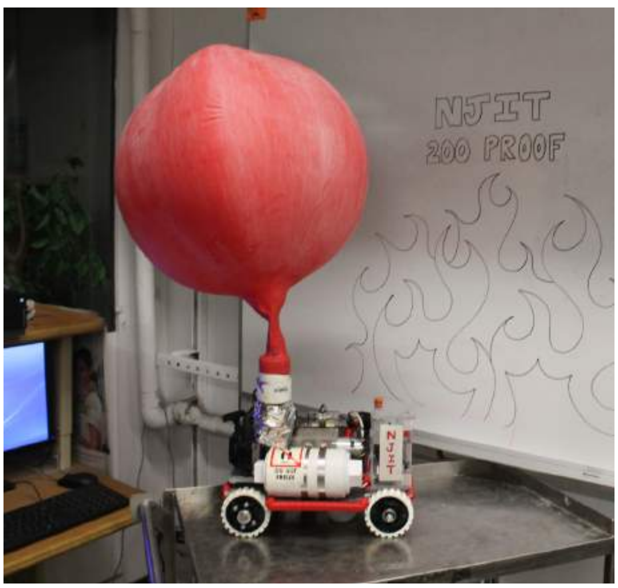
Do you have a passion for robotics and chemistry? If you do, Chem-E-Car is the right place for you! Chem-E-Car is an annual competition that was created by the American Institute of Chemical Engineers (AIChE) to encourage college students to design and construct a car powered by numerous chemical reactions. There are many creative ways to utilize chemical reactions to both power a car and control the distance it travels. In the realm of robotics, Chem-E-Car is part of the subset that utilizes chemistry in soft material and microscopic bacterial robots. On-board computers, such as Arduinos, are used to detect the end of a reaction to force the power source to shut down. The main goal of the competition is to create a car that will safely carry up to 500 mL of water, travel 15 to 30 meters in less than 2 minutes, and stop by itself using chemical power and timing reactions.[1] Ordinary cars are powered by gasoline engines; the NJIT Chem-E-car, on the other hand, uses ethanol to power the car's small weed whacker engine. A simple example of a timing reaction is the baking of bread, in which yeast takes a certain amount of time to activate and inflate dough to a certain size. Similarly, the team representing NJIT in the AIChE competition uses transition glasses that become dark in the presence of UV light during a certain period of time to function as the stopping mechanism.

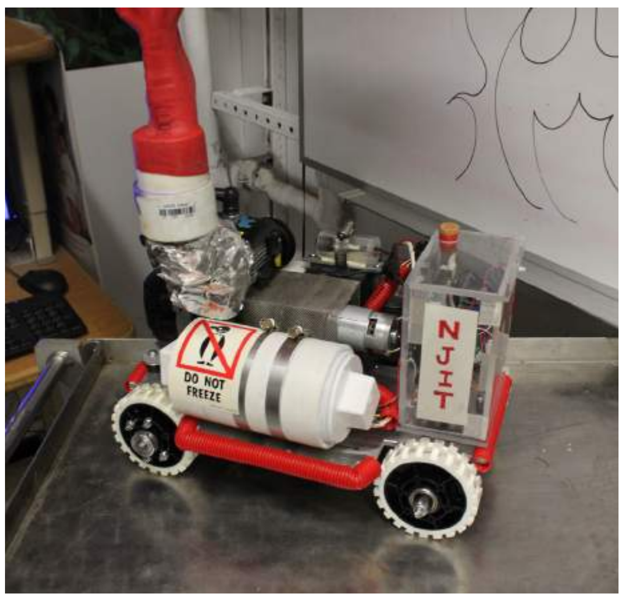
Robotics extends the spectrum of possibilities for designing and constructing a car, allowing all types of engineers to have an impact on the Chem-E-Car. NJIT's team has members not only in chemical, but also in electrical, computer, and mechanical engineering. The fuel source is the product of chemistry, but it is only a small part of a larger mechanism. It is imperative to know how the engines work, how the circuitry is connected, and how the programming is written to create a complete product which is the "200 Proof" car, NJIT's 2014 submission.

"200 Proof," named after the purity of the ethanol fuel, has three main components: an Arduino, transition lens, and an engine. The Arduino provides the computational logic that connects the two chemical reactions – the lens and the engine. The transition lens used is made of the chemical compound azobenzene. When the lens is exposed to UV light (i.e. sunlight), the azobenzene slowly changes state and alters the color of the lens to a blackish-blue color.[3] The change of state and color is crucial to the mechanism because it signals the completion of the reaction to the Arduino. At the same time, the engine houses the ethanol fuel which combusts upon exposure to oxygen, moving the pistons. The oscillation of the piston generates the electricity that is used to power the motor. The Arduino is pivotal in connecting the two processes seamlessly.

The Arduino detects a signal from the lens reaction and converts that signal into a termination command for the engine. The Arduino is connected to the different constituents of the car's lighting system, which consists of one ultraviolet light bulb, LEDs, and a light sensing component. The LEDs are constantly emitting light to the sensors, while the UV bulb emits light to the lens. As sufficient time passes, the lens becomes darker due to UV exposure, preventing the sensors from detecting any light from the LEDs. This change prompts the Arduino to turn the engine off. The diagram on the next page can be used as a visual aid.

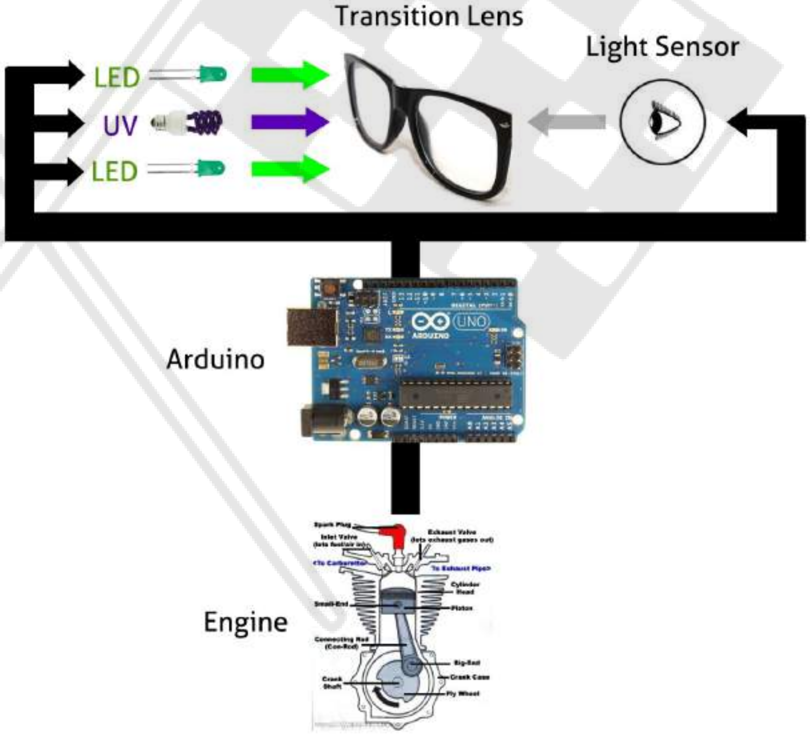
How do other teams use an on-board computer in their Chem-E-Cars? Everyone uses essentially the same set up: they have a power source similar to the engine, except they may use a fuel cell or a battery instead.[2] A color changing component may also be present, much like the transition lens, except with a chemiluminescence reaction or an iodine clock reaction.[2] Although chemical reactions are what power the car for a specific amount of time, the on-board computer controls the signals between the reactions.





The triple faceted Chem-E-Car – time reaction, onboard computing, and power reaction – comprises a simple yet powerful schematic. What makes this such a powerful learning tool is the simple marriage of chemistry and robotics: neither can be successful without the other in this endeavour.

TIMING REACTION MECHANISM



DEEP SEA ROBOTS IN SPACE

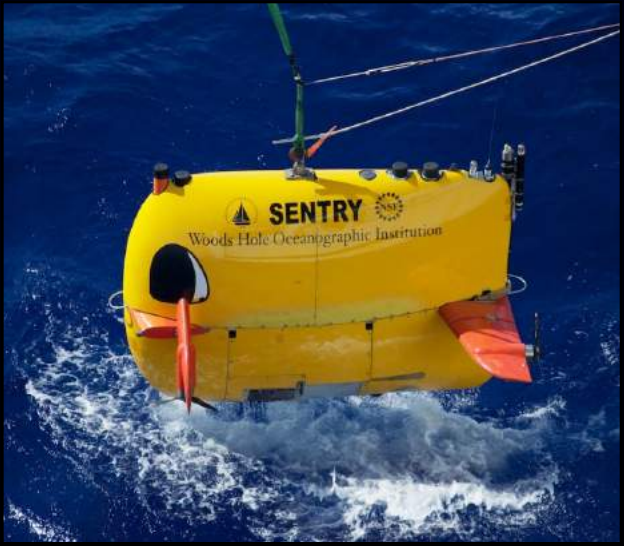
HARI RAVICHANDRAN

Imagine a robot that travels underwater. A robot that thinks for itself and that makes its own decisions. What could likely be described as the future is already here. These robots are called Autonomous Underwater Vehicles or AUVs. AUVs are currently used for a myriad of applications in the military, ocean exploration, environmental monitoring, and the petrochemical industry. Compared to manned submarines and underwater ROVs (Remotely Operated Vehicles), AUVs are less expensive, have the advantage of independent operation, and can explore places deemed unsafe for humans. AUVs are seen as promising tools by organizations such as NASA, Woods Hole Oceanographic Institution, and Bluefin Robotics which are developing them for research, commercial use, and future space exploration.


DEPTHX

Due to their robotic nature, AUVs are highly useful for navigating places where human travel is difficult or impossible, such as a body of water underneath an expansive sheet of ice. As a matter of fact, NASA believes that there is likely to be a large ocean underneath Europa's icy surface based on data they gathered from the Galileo Spacecraft in 1995.[1] Based on this information, NASA scientists believe Europa is a prime candidate for life outside of Earth. They are confident enough to plan another expedition, the Europa Clipper mission, to conclusively determine if Europa has a subsurface ocean worth exploring.[2] If true, an AUV could be the perfect vehicle to send on a future mission to explore this ocean.

To this end, NASA funded the creation and testing of an AUV called DEPTHX that was designed in 2007 by Bill Stone and his team at Stone Aerospace. DEPTHX was created to explore sinkholes and collect biological samples for further study in Rancho La Azufrosa, Mexico. The sphere-shaped robot the team designed was able to successfully navigate through the water while collecting biological samples and mapping its surroundings in three dimensions. This mapping was accomplished by fifty-six sonars that fired in rates of up to four times per second to collect information about the surroundings. Moreover, the AUV was programmed to have the unique ability to determine the next course of action in a given situation. For example, the AUV can decide where to navigate, what to do when a part fails, and when to gather samples for investigation. The DEPTHX navigates using a SLAM (Simultaneous Localization and Mapping) method in which it continually establishes its location using sonars that can reach up to 300 meters, and moves accordingly. The AUV also employs a piece of software written by researchers at Carnegie Mellon University that allows it to choose an action based on a situation. The software monitors conditions including depth, battery voltage, location, vehicle orientation, leaks, temperatures, thruster faults, and disk space. Once a failure occurs, the vehicle detects it using its onboard sensors and forms an escape plan based on the working parts that it has left. If a higher level system fails, the AUV falls back on a more primitive approach. For instance, the ideal escape plan for the vehicle would involve it navigating using its pose control (navigation) system, sonars, and velocity control system. The pose control system is responsible for higher-level navigation; the sonars detect obstacles and walls; and the velocity control system allows for precise control of the movement. In a situation when the ideal escape plan is necessary, the AUV would intelligently navigate to the top of the sinkhole using all three systems. If the pose control system were to fail, the craft would move upwards, using sonars to detect obstacles and moving horizontally in the opposite direction to avoid them. If both the pose control and sonar systems were defective, the craft would just blindly move upwards. Due to its functionality, the DEPTHX robot was able to successfully explore three sinkholes in Mexico, map them, measure their depths, and sample the unique microorganisms contained inside to discover never before seen divisions of bacteria [3][10][11]



From the end of 2008 into 2009, Stone Aerospace developed the ENDURANCE, an improvement on DEPTHX that was designed to go on a mission to map West Lake Bonney in Antarctica. Compared to DEPTHX, ENDURANCE has an improved navigation system, a larger sensor array, and an attached probe. The probe can extend up to 100 meters beneath the AUV to reach regions where it would be hard for the AUV to travel. Lake Bonney is covered with ice much like the oceans on Europa. Because of this layer of ice, first, a hole had to be melted through the ice cap to lower the submarine through. The AUV was then able to successfully explore the lake and was the first explorer to collect considerable data for researchers on Lake Bonney.[3][5]

Another AUV that has been designed to explore the ocean floor is the Sentry, an AUV that has the ability to safely descend to depths of up to 6,000 meters. This AUV was created by the Woods Hole Oceanographic Institution and is capable of taking pictures of deep sea terrain and operating on deep-sea vents, mid-ocean ridges, and underwater volcanoes. The Sentry is also equipped with several sensors that measure variables such as depth, velocity, oxygen, and magnetic fields; other sensors allow Sentry to collect biological samples. Recently, this AUV has been used to explore underwater areas in the Pacific Ocean, the Gulf of Mexico, the Mid-Atlantic Ridge, and the Galapagos Islands. In March 2015, the AUV is scheduled to travel to New Zealand in order to explore four active underwater volcanoes off the coast. This expedition will be the first close examination of the volcanoes and is a joint effort of the Woods Hole Oceanographic Institution, GNS Science, and the Royal

New Zealand Navy. [6][7]

AUVs are not only used by researchers but also by corporations for finding natural resources underwater, salvaging items from wreckage, exploring the seafloor, and inspecting ship hulls. In fact, several companies including Bluefin Robotics and Teledyne sell torpedo-shaped AUVs to corporate customers. The torpedo shape is often chosen because it reduces drag on the AUVs which conserves power, and is useful for mostly linear travel. These commercial AUVs range from compact (for use in shallow applications) to larger sizes for deep-water exploration. For instance, Bluefin Robotics makes a variety of AUVs that are suited for commercial, scientific, and defense applications. The different AUV models offer customers the opportunity to choose the type of AUV that best fits their purpose.[8]

As AUVs are a relatively new field, there is a lot of potential for improvement. Several areas in which improvements are needed include battery life, overall design, and artificial intelligence. Most existing AUVs have a battery life of tens of hours, which is acceptable on Earth but not enough for space exploration which would require a battery that lasts at least a few months, since there is no external source of power. For example, the AUV Sentry takes up to four hours to reach the ocean floor from the surface, and can take measurements for a maximum of twenty-four hours before it needs another four hours to resurface. [6] Many current AUVs use lithium ion batteries, but alternative technologies such as fuel cells or a RTG (Radioisotope Thermoelectric Generator) may be needed to increase the operating life of an AUV. [9] The option of using solar panels to power the vehicle is out of the question because there is not enough light in the depths of a body of water or below a sheet of ice to power an AUV.

There is a long way to go before AUVs can be sent to outer space. One of the major concerns for a space mission is the possibility of a part failing, which ENDURANCE addresses by being fully redundant with two power supplies and multiple thrusters and propellers that allow the craft to move in three dimensions.[4] ENDURANCE has six thrusters: four horizontal and two vertical.[4] Any two horizontal thrusters and one vertical thruster can maneuver the submarine in any direction.[4] As for autonomy, researchers and engineers have to improve the ability of AUVs to make decisions in an emergency situation. In 2005, the torpedo-shaped AUV Autosub got stuck while traveling under Antarctic ice. [3] It sent out an emergency signal, but the scientists had no way of recovering the submarine, as it was roughly 17 kilometers from the edge of the ice and 200 meters under ice at that point.[3] In order to prevent incidents like this from happening again, future robots need to have artificial intelligence that allows them to handle emergency situations with minimal damage and loss of data.

Researchers are experimenting with different AUV designs as shown by DEPTHX, ENDURANCE, and Sentry for applications in oceans across the world. AUVs have already proven their worth in a myriad of commercial, research, and military applications. Through using AUVs, we can explore new regions previously deemed unsafe for expeditions. Once AUV technology has advanced far enough, it may be used to further explore our world and even distant worlds.

Earthquake Rescue Robots

Abhishek Trivedi

In March 2011, one of the worst earthquakes ever recorded in human history, with a magnitude of 9.0, hit off of the Pacific coast of the Tohoku region in Japan. The earthquake and the subsequent tsunami it initiated killed over 15,884 people and inflicted severe damage to many nuclear reactors located in Japan.[1] Despite the death, destruction, and damage that resulted from the earthquake, one positive aspect was the historically smooth and quick recovery effort. One of the main reasons for this was the use of specialized robots in the recovery mission. This helped the country look for survivors and dampened the destruction caused by the earthquake. This combination of Japan's vulnerability to earthquakes and its advanced robotics industry has led to the creation of many different recovery robots. These robots continue to be further developed to aid with recovery efforts of future natural disasters.

One of these revolutionary robots is dubbed the RoboCue. It is officially part of the Tokyo Fire Department and is routinely used to locate and safely remove victims from disaster sites. This remote-controlled robot was released in 2009 and uses infrared cameras and ultrasonic sensors to locate trapped humans. Once it locates a human, it

Robocue, the Tokyo Fire Department's Rescue Bot

gently loads the person on itself using a robotic arm and conveyor belt so that the individual can be transported to safety.[2]

A different sort of robot, but one that is also used in search and rescue missions, is the innovative Snakebot. Although there are many Snakebots, Satoshi Tadokoro has recently developed a twenty-six foot long robot that is only an inch thick allowing it to squeeze through the smallest of gaps, turn sharp corners and climb small inclines. This particular Snakebot has successfully been used in a parking lot collapse in Florida, sending back pictures to allow the rescuers to evaluate the disaster site and locate survivors. Another robot that is geared more for the 'search' part of the whole search and rescue mission is the Breath-Sensor from the Chiba Institute of Technology in Narashino, Japan. This small robot finds survivors by using infrared sensors to detect body heat and carbon-dioxide sensors to sense exhaled breath. At first glance, the robot looks like a child's toy car, but it is much more complex than it seems. Its sophisticated design includes 3D mapping technology and a speaker so that rescuers can locate and communicate with victims. Further, it can act as a vehicle to transport small survival items such as water, food, or a cell phone.[4]

Firefighters carry out relief work

Besides these, there are many other robots currently being used in disaster situations. For instance, the robotic safety crawler can carry up to a 250 pound person to safety while monitoring the patient's vital signs such as blood flow. Another robot from Japan is called the roller-skating robot. Although the name may sound perplexing, this ingenious robot has legs that can convert to wheels when necessary so that it can move faster when stable, flat ground is available. Some of these roller-skating robots are reconnaissance robots, while many of them are transport robots. The reconnaissance robots look for survivors using either cameras or sensors, while the transport robots safely remove victims from the disaster area. When used in combination, these robots have the potential to replace human rescuers. These robots are also stronger, and more resilient and effective, using state of the art sensor technologies. However, most importantly, they are less precious than human life and can greatly improve the outcome of rescue missions.

Example of an Unmanned Aerial Vehicle

As technology has advanced exponentially in the last 20 to 30 years, so have robotics and instruments that aim to make our lives easier. New developments ranging from advanced prosthetics to telepresence devices change the way we live and interact with others. The goal of these advancements is to make our lives easier. To this end, companies such as Amazon and Google have started developing delivery drones that could save time and potentially lives as well.

Amazon Prime Air

In late 2013, Amazon CEO Jeff Bezos revealed Amazon's daring plans for an air delivery service called Prime Air.[1] Prime Air is a delivery service powered by "Octocopter" delivery drones that could deliver a package to a home on the same day the order is confirmed. The Octocopter drones are limited to packages of a certain size and weight[2], and are able to deliver the packages and return to the warehouse.[1] Prime Air could very well revolutionize the way we shop. In the very fast paced world that we live in, shipping can sometimes be a nuisance. With Prime Air, a customer would be able to order something online and get it shipped to their doorstep within half an hour of completing the order.[1]

This technology is not only limited to shopping. The Octocopter drones could also be extremely useful in mapping, aerial photography, wireless internet, endangered species monitoring, and law enforcement assistance.[3] Endangered species could be monitored via the Octocopter drones without disturbing habitats. The drones could be used for photography and terrain mapping in the same way. Law enforcement could also be assisted with the drones. Similar to traffic light cameras, the drones could monitor certain areas of cities to surveil for crime. Still, using drones for surveillance could bring up ethical issues of invasion of privacy. Although shipping will probably seem like the most important use of these drones, other uses could also prove to be tremendously valuable.

Quite similar to Prime Air and its Octocopter, Google is also in development of a drone delivery service, Project Wing.[4] Although Project Wing can also be used as a delivery service to customers, the project's main focus is disaster relief. Project Wing also differs from Prime Air in that the design is significantly different. Wing resembles a mini airplane with 4 propellers and a wingspan of 5 feet, unlike the Octocopter which has 8 rotors.[4] It can also take off and land without a runway and weighs around 19 pounds.[4] Another difference from the Octocopter is that Wing does not actually land to deliver supplies. Instead the supplies are lowered down by a fishing line and released.[4] With this design, Google aims to use Project Wing to deliver supplies to areas that are hazardous for soldiers and volunteers. Using drones in this way would prevent putting lives in danger to assist in disaster relief efforts. One situation in which this technology would have been useful is the recovery efforts in New Orleans after Hurricane Katrina. Aid was unable to come to the city due to the storm. Many people resorted to looting to get needed supplies. Project Wing could have been used in such a situation to deliver food, clothes, medical supplies, and water.

A drone delivering water

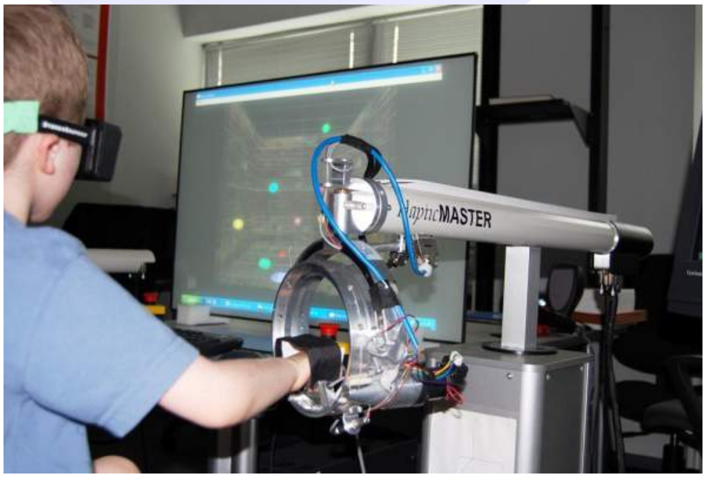
It is clear to see that both Prime Air and Project Wing can save people much time. This is especially beneficial in an age in which time is extremely valuable. That being said, the idea of having drones flying around US cities could be quite daunting. In light of recent events, drones are seen by many as death machines. Furthermore, if drones were used as law enforcement "assistants," arguments on ethics and personal privacy could be brought up. For some, surveillance drones in residential areas are an invasion of privacy. Both Amazon and Google need to continue working on the software controlling their respective drones to account for variables such as wind, unexpected obstacles in the air or on the ground, and battery life.[2] Further, neither drone program can begin without federal approval from the Federal Aviation Administration and the Federal Communications Commission.[3] With this in mind, drone delivery services definitely have some hurdles to address in the near future before they are implemented nationally. Still, drones could be successful if the proper precautions are taken for shipping supplies, either in disaster areas or to residential homes, and especially if used for mapping and endangered species monitoring.

The HAPTICMASTER Programmable Robot Arm

Sahitya Allam

Haptic interfaces that enable human-machine communication through an intermediate device represent the future of user experience in robotic technology. Through haptic interfaces, users receive mechanical feedback in the form of sensations, known as "haptics," in the hands or other parts of the body. In combination with a visual display that, in effect, creates a virtual reality or 3-D environment, haptic interfaces can be used to train people in tasks requiring hand-eye coordination.[1] Recently, haptic technology and virtual reality programs have been increasingly utilized to help individuals such as stroke victims regain their lost motor function.[2] A prime example of this innovative technology is the HapticMaster Programmable Robot Arm, which is a haptic device that requires force input and redirects force output to allow users to fine-tune the movements necessary for performing a variety of everyday human tasks.[3] The Robot Arm operates according to the "admittance control" paradigm, meaning that the device reacts with a displacement that correlates to the force applied by the user in order to produce a certain effect in the virtual world.[3] Admittance control devices can be very robust, displaying high stiffness and a minimal amount of friction that is suitable for a wide range of motion.[3] This type of control is appropriate for large workspaces and for carrying complex position and velocity end effectors, the devices that are attached to the end of a robot arm. However, every seemingly beneficial application does not come without drawbacks, and the HapticMaster is no exception. For instance, it is not capable of registering the forces transmitted by low masses, but fortunately, its widespread use in neurorehabilitation research does not require this ability.[3]

The control algorithm of the HapticMaster is comprised of an outer control loop and an inner servomechanism, which is a type of error-sensing mechanism that corrects the performance of the robot.[3] The virtual model converts the signal transmitted by the force sensor that detects the magnitude and direction of the inputted force into a position-velocity-acceleration (PVA) vector.[3] The inner servo loop adjusts the robot according to the PVA vector values.[3] A schema of the control algorithm is depicted in Figure 2. The hardware of the HapticMaster is composed of two main components: the robot arm and the control box. The robot arm is built for low levels of friction, resulting in smooth movement at the end effector.[3] The end effector can be changed based on the application. For example, an end effector with three additional rotations that acts as a torque sensor can be mounted at the end plate of the robot arm; other common examples of end effectors include grippers that enhance the virtual experience by allowing for more dexterous movements.[4] The ability to easily incorporate end effectors into its design makes the HapticMaster a very flexible device that can be used for a wide range of applications in many fields of research, such as robot rehabilitation and virtual reality. The haptic renderer and robot control loop of the HapticMaster both run on the VxWorks real-time operating system at an update rate of 2500 Hz.[3] This frequency is almost ten times higher than the maximal human discrepancy value, the rate at which humans can differentiate between changes in a force vector, and therefore, assumed to be high enough to guarantee good haptic quality to ensure a realistic experience for the user.[3] The HapticMaster is programmed by means of a HapticAPI, which is a C++ programming interface that enables the user to control the HapticMaster and create virtual worlds with which the HapticMaster can interact.[5]



At NJIT, there are a number of research labs that have used the HapticMaster Robot Arm in rehabilitation studies. Dr. Richard Foulds, Associate Professor in the Department of Biomedical Engineering, used the HapticMaster to help children with cerebral palsy so they could develop better manual coordination.[2] Dr. Foulds and his research team accomplished this by connecting the HapticMaster to a virtual program that required the children to perform intense, repetitive arm and finger motions.[2] By using the HapticMaster to guide their movement in the virtual world, the children were able to learn the proper movements in a fun and engaging way. Dr. Sergei Adamovich, also an Associate Professor in the Department of Biomedical Engineering, currently uses the HapticMaster to help stroke victims overcome spasticity, or rigidity of the muscles. His research team also investigates the potency of using virtual reality games to assist stroke victims in re-learning basic motor movements.

Until recently, prosthetic technology has remained relatively stable with little change. The best hope for an amputee was to have a replacement limb that restored some functionality and resemblance to the original limb, though suffering from the lost functionality was expected. Yet, certain patients never adjusted to a prosthetic extremity and experienced more difficulties rather than relief. Moreover, the discomfort and limited function of the prosthesis often resulted in its abandonment.[1]

History is littered with wars, accidents, and birth deformities. Hence, it is reasonable to presume that efforts to create prostheses are as old as humanity. However, given the limited technology of the past, the initial objective was improving the appearance of amputees rather than providing functional needs or solving a medical problem. Fast-forward to the modern era of prostheses with functional enhancements and the ability to feel objects – a reality owing to a medical concept called reinnervation that restores lost nerve function.[2] Targeted Muscle Reinnervation (TMR) is a surgical process that reassigns the nerves of a lost limb to other muscles, enabling prosthetic technologies with automated mechanisms to exploit the neural excitement of a muscle.[3]

When it comes to prostheses, aesthetic appeal is important from a psychological viewpoint. However, even if the shape of the prosthesis is an exact replica of the missing limb, the fit is actually key to its usefulness to an amputee. If the fit is compromised, not only is functionality lost, but resulting pain and accidents may also occur. New smart materials that are flexible and lightweight are now increasing the dexterity and agility of artificial limbs, allowing the design of prostheses that are more comfortable than previous ones.

Bionic devices for limb replacement were once seen only as fictional gear for attaining super-power abilities.[4] Now, they are commonly used in medical practice, particularly for lower extremities. Similarly, directing prosthetic devices to perform actions via brain control has gone from the imaginary stage to an experimental one. Thanks to the contribution of significant funds towards prosthetics research, limb replacement technology has advanced to replicate normal flesh and bone, offering mobility, feeling, and functionality to those in need.[4]

There is promising potential for new prosthetic technology to work just like actual limbs. The distinction between the feel of real and synthetic limbs is blurring. More importantly, the prospect of life without physical disability is coming closer to reality. Research laboratories are trying to create new tissues in Petri dishes, with some early successes, but more work is needed before a new limb can be regenerated. In the meantime, researchers are developing artificial skin with the form and functionality of human skin using carbon nanotubes and new polymer materials.[5] Carbon nanotubes are long, hollow structures with distinct mechanical, electrical, thermal, optical, and chemical properties. Even though synthetic skin does not function exactly like natural skin, this engineered tissue provides contact with the natural skin at the amputation site, allowing the tissue to become stimulated with electrical pulses so that a prosthetic device can touch and sense naturally [6] (Figure 1).

Prosthetic fit has always been an issue for patients. Typically, users manually adjust the connection between their devices and residual limbs. This is why the site between the person's body and any potential prosthesis is of utmost importance for surgeons treating the wound. However, it is not always possible to create an amputation stump that results in a perfect prosthetic fitting at the time of surgery. To avoid musculoskeletal injuries, amputation-prosthesis interfaces are designed to improve comfort and reduce pain.[7] This depends on a number of factors, including the shape of residual limb conditions, which makes this an intricate task. Furthermore, it is not feasible to expect that multiple apparatuses will be used to accommodate a person's everyday physical activities, as this will be both impractical and cost prohibitive to many members of society. Thus, it is necessary for prosthetic devices to emulate the full range of normal physiological functions of the human body. For example, in the case of designing prosthetics for lower extremities, there is a need to take into consideration the activities of walking, running, or simply sitting down.[7] The Biomechatronics research group at the Massachusetts Institute of Technology Media Lab is concerned with precisely this type of research in which breakthrough models of human physical activities are being developed.[8]

Thought-controlled artificial limbs (Figure 2) that detect differences in texture, temperatures, and pressures through prosthetic sensors wired to sensory nerves in an amputee's body hold promise. Such myoelectric signals generate muscle actions that mimic the control of human anatomical motions and movements. For example, a myoelectric, pattern-recognizing artificial leg can communicate with nerve signals emanating from an amputee's stump in response to amputee intentions to climb stairs, stand up, or run.[9] Clearly, the control of such externally powered prosthetics requires delicate human-computer interaction.[10] More research and development efforts are still needed for such prosthetic devices to be routinely used.

The convergence of biomechanics, neuroscience, robotics, and prostheses design is a complicated engineering challenge. Clearly, sophisticated signal processing between an amputee's brain and a prosthetic device is vital for communication among nerve endings in the skin, neurons in the brain, and muscles. Similarly, further development of the new synthetic skin is still required so as to better integrate the numerous electromechanical parts, including sensors and metallic prosthesis components, into a natural-looking bionic limb. Thus, while there has been significant progress, more engineering work is needed before an artificial limb can function as well as its human counterpart. However, such a goal is getting closer to reality, with potential uses beyond the medical realm.

Evolving technologies in a number of domains – physical, biological, and natural – are now converging in various ways to improve human lives. In fact, the applications for new prosthetic technology are expanding. Not everyone who is using bionic devices is actually in need of prosthetics.[12] For example, some competitive athletes have been early adopters of such devices. The bionic benefits of using less energy at a desired speed while reducing musculoskeletal stress and easily navigating difficult terrains is appealing. This type of biotechnology enhancement in a non-health related manner is carried out strictly to improve physical capacity.

Yet technology alone is not the answer to improving the quality of life. Despite scientific and technological advancements, we are constrained regardless of what tools we may have at our disposal without a positive attitude, patience, persistence, and personal responsibility. Amputee attitude plays an important role in the success or failure of prosthetic devices. Awareness of various options available to amputees will help individuals make appropriate choices for their needs and mitigate unrealistic user expectations. New technology is facilitating the complex transition of the field of prosthetics from its predominantly visual root to the era of bionic devices. But the high adoption failure rate cannot all be attributed to patient difficulties with such devices.[13] As with any assistive tool, there is usually a learning curve in understanding its capabilities. Amputees and their healthcare providers stress that dedication to rehabilitation and patient cooperation are necessary elements for success. One should be mindful that prostheses are assistive tools that require patience and practice to exploit their full functionality.

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IMAGE OF NJIT

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