LIFE-LIKE PROSTHETICS

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Imagine not being able to change your car stereo without looking because you cannot feel what the buttons are shaped like? Fortunately, for Jesse Sullivan, who lost both his arms, this is not a reality. Sullivan, a former Tennessee power company electrician, was fitted for both his "bionic arms" under the care of Dr. Todd Kuiken at the Rehabilitation Institute of Chicago (RIC). These "bionic arms" were the first prototype robotic arms (dubbed "Proto 1") available in the world. The technology behind Proto 1 evolved from a slightly older technology known as the BrainGate, which was developed by Cyberkinetics Neurotechnology Systems, Inc., to sense, transmit, analyze and apply the language of neurons.

Jess Sullivan and "Bionic" Arm

BrainGate

The BrainGate Neural Interface System is used as an investigational medical device and is currently the subject of pilot clinical trials. This system includes a small (4x4 millimeter) sensor device containing 100 tiny electrodes which are implanted on the surface of the brain's motor cortex. The motor cortex of the brain generates neural impulses which control the execution of movement. The electrodes of this system detect electrical signals from nearby neurons and transmit them to a titanium pedestal that protrudes about an inch above the patient's scalp. A cable then carries these signals from the pedestal to an external device such as a computer. Algorithms are then designed to translate these neuronal signals detected in the motor cortex into machine language – a language that a computer can understand. Thus, these external devices are capable of moving a robotic arm or a computer cursor.

The First "Bionic" Arm (Proto 1)

Dr. John P. Donoghue, founder of Cyberkinetics Neurotechnology Systems Inc., first developed and tested the BrainGate technology on monkeys in his lab at Brown University in 2003. In the initial tests, a sensor implanted into a monkey's motor cortex, detected and recorded neural activity while the monkey controlled a computer cursor with a joystick. The relationship between the movement of the joystick and the "spikes" created by neurons was then used to create a mathematical model. This model, which consisted of a set of signal patterns, was then used to develop a physical model, presumably the first BrainGate system. As a part of these tests, a monkey was instructed to play a computer game with a joystick. After a while, the researchers turned off the joystick and substituted the signal from the sensor only to observe that the monkey successfully continued to play the computer game.

Not long after the tests with the monkeys were completed, human tests began. In 2004, Cyberkinetics Neurotechnology Systems Inc. installed the BrainGate system on a quadriplegic patient so that he could also move a computer cursor. This patient was able to perform a mouse click by leaving the cursor in the desired location for a short while. Thus, the patient effectively used a computer to watch TV, check email and play a computer game.

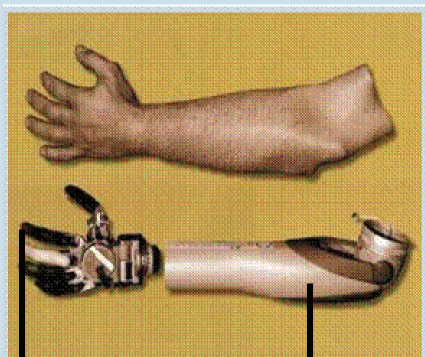
With the trial's success, it is predicted that patients will soon be able to mentally control a motorized wheelchair and other electronic devices. Also, it is hoped that people with other severe motor disabilities will be able to regain limb control with the use of this technology. At Duke University, monkeys successfully moved an object from one place to another by means of a robotic arm designed using the BrainGate. Thus, the BrainGate is making progress with prosthetics even though it is under clinical trials.

Proto 1 and Proto 2 : Thoughts become Reality

One of the most recent advancements in prosthetics is Proto 1, a wireless version of the BrainGate. At the RIC, Dr. Richard F. Weir and Dr. Todd Kuiken in conjunction with Sigenics Inc. and Chicago PT LLC, created wireless transmitters that will be injected into the patient's remaining chest and shoulder muscles to control an artificial arm. When the brain stimulates the nerves, impulses are sent to electrodes on the chest that tell the arm to move. The hope is that eventually this prosthetic arm will perform like a real human arm so that the users can carryout actions such as playing a guitar or threading a needle.

Not only does Proto 1 provide the patient with control over the prosthetic through thoughts, it also provides sensory feedback for the individual and increases the mobility to eight-degrees of freedom. One main contribution for Proto 1 , developed by Dr. Kuiken, is the Targeted Muscle Reinnervation Technique (TMR).

Prosthetic vs. Human arm

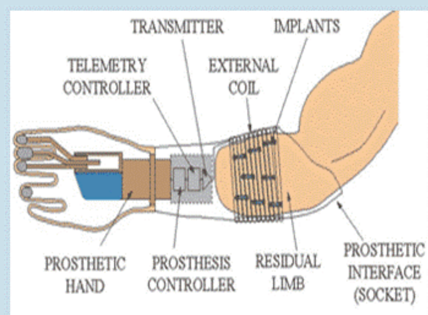


Arm is built with **durable** material, able to function for at least 24 hours, and it is also **Waterproof** and resistant to heat, cold, and humidity.

Fingertip **sensors** can detect temperature, pressure, and vibrations. Knuckles can bend and fingers can wiggle.

TMR is a technique that transfers residual nerves from an amputated limb to unused muscle regions close to the area of injury. In Sullivan's case, the shoulder nerves were transferred to his pectoral area. This technique increases the functionality of the prosthetic arm by allowing the patient to experience the sensation of grip, strength and touch. Sensors for temperature, pressure, and vibration will be used to stimulate a patch of skin, thus tricking the brain into feeling what the prosthetic arm feels.

After the success with Proto 1, Dr. Weir and Dr. Kuiken continued their research to develop a more advanced prosthetic called Proto 2. One significant addition to Proto 2 is the Injectable MyoElectric Sensor (IMES). The background behind IMES is that when a muscle contracts it generates electrical signals (the Electromyogram or EMG). These electrical signals can be detected and measured with an electrical sensor. The EMG signals can be sensed and telemetered out to the controller in the prosthetic and cause multi-functional con-



Schematic of planned Implanted Myoelectric Sensors (IMES) system.

trol of the prosthetic, as shown below. The sensors receive their power, digital addressing, and command signals from a transmitter coil in the prosthetic socket by forward telemetry. Simultaneously, EMG data will be sent to the prosthetic control by reverse telemetry from the implants.

RIC predicts that the addition of IMES to the TMR will lead to more than twenty-five degrees of freedom, more than eighty sensory elements for touch, temperature, and position, and an increase in the speed and strength to almost the capability of a human limb. Additionally, Proto 2 is expected to be unveiled at the end of this summer.

Hopeful Future

Since the development of the "bionic arm," there is the possibility of expanding the technology to the use of an artificial eye by applying the BrainGate chip mentioned above. The goal is to implant an electrode array into the visual cortex, with a camera placed on the eye glasses that the blind or people with impaired vision wear. This camera will send video signals through the electrodes, stimulating neurons in the brain so that the person is able to coherently interpret these signals.

In addition to the eye glasses, many scientists have also pursued the development of an artificial retina in order to form better images. The same chip used in Proto 1 and Proto 2 now provides images directly onto the artificial retina, and therefore simplifies the technology of the artificial eye. The design of man-made eyes is extremely difficult due to the wide range of lighting conditions under which human eyes typically function. It is hard for man-made vision systems to project clear, high-resolution color images in very dim lighted conditions, and it would be hard for the patients to visualize the images also. Although sensors still cannot provide the exact vision and resolutions that natural eyes would, they will prove to be indispensable gadgets for the blind and people with impaired visions in the future. The technology is still under development, but soon the prosthetic eyes will be the next exciting development in the fields of neural sensors and prosthetics. The BrainGate, Proto 1 and Proto 2 technologies make the unattainable attainable.