International Journal of Advanced Scientific Research
ISSN: 2456-0421; Impact Factor: RJIF 5.32
www.allscientificjournal.com
Volume 1; Issue 6; September 2016; Page No. 04-08

Octobot - An entirely soft and autonomous robot

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Abstract

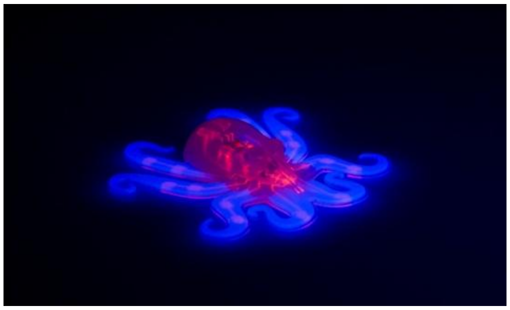
An Octobot is an autonomous and soft robot which is shaped like a small octopus. This paper explains about how robots came into existence and idea of making an Octobotarose. The study of differences between a mechanical and a soft robot is significantly mentioned. Also, there is a brief discussion about other animals which have inspired from soft robots. It gives knowledge on how an octobot works. The main focus is on various advantages of using octobots.

Keywords: Octobots, soft robot, autonomous, liquid fuel, 3D printing.

Introduction

The Octobot is an entirely soft, autonomous robot. The robot is shaped like a small octopus. It uses hydrogen peroxide as a power source and has a microfluidiclogic circuit. It is designed to mimic that slithery creature to get through cracks and tight places, making it ideal as a rescue robot. Octobot is a proof of concept for the first fully soft-bodied autonomous robot.

A rubbery little "Octobot" is the first robot made completely from soft parts. The tiny, squishy guy doesn't need batteries or wires of any kind, and runs on a liquid fuel. The octopus-like robot is made of silicone rubber, and measures about 2.5 inches (6.5 centimetres) wide and long. It has 8 arms.



A pneumatic network (red/ pink) is embedded within the Octobot's body and hyper elastic actuator arms (blue).

What is robot: A robot is a mechanical or virtual artificial agent, usually an electromechanical machine that is guided by a computer program or electronic circuitry, and thus a type of an embedded system.

Robots can be autonomous or semi-autonomous.

Robotics: The branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing is robotics. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behaviour, and cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics. These robots have also created a newer branch of robotics: soft robotics.

Soft robotics: It is a relatively new field in robotic engineering that uses materials like silicon to create soft and flexible devices capable of behaving in a manner unlike traditional robots. Potential benefits include resilience, cost effectiveness and manoeuvrability.

History of Robots: The term 'robot' was first used to denote fictional automata in a 1920 play *R.U.R.* by the Czech writer, Karel Čapek. However, Josef Čapek was named by his brother Karel as the true inventor of the term robot.

In 1928, one of the first humanoid robots was exhibited at the annual exhibition of the Model Engineers Society in London. Invented by W. H. Richards, the robot Eric's frame consisted of an aluminium body of armour with eleven electro magnets and one motor powered by a twelve-volt power source. The robot could move its hands and head and could be controlled through remote control or voice control.

Westinghouse Electric Corporation built Televox in 1926; it was a cardboard cut-out connected to various devices which users could turn on and off. In 1939, the humanoid robot known as Elektro was debuted at the 1939 New York World's Fair. Seven feet tall (2.1 m) and weighing 265 pounds (120.2 kg), it could walk by voice command, speak about 700 words (using a 78-rpm record player), smoke cigarettes, blow up balloons, and move its head and arms. The body consisted of a steel gear, cam and motor skeleton covered by an aluminium skin. In 1928, Japan's first robot, Gakutensoku, was designed and constructed by biologist Makoto Nishimura.

Modern autonomous robots: The first electronic autonomous robots with complex behaviour were created by William Grey Walter of the Burden Neurological Institute at Bristol, England in 1948 and 1949. He wanted to prove that rich connections between a small numbers of brain cells could give rise to very complex behaviours - essentially that the secret of how the brain worked lay in how it was wired up. His first robots, named *Elmer* and *Elsie*, were constructed between 1948 and 1949 and were often described as *tortoises* due to their shape and slow rate of movement. The three-wheeled tortoise robots were capable of phototaxis, by which they could find their way to a recharging station when they ran low on battery power.

Walter stressed the importance of using purely analogue electronics to simulate brain processes at a time when his contemporaries such as Alan Turing and John von Neumann were all turning towards a view of mental processes in terms of digital computation. His work inspired subsequent generations of robotics researchers such as Rodney Brooks, Hans Moravec and Mark Tilden. Modern incarnations of Walter's *turtles* may be found in the form of BEAM robotics.

The first digitally operated and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate. This ultimately laid the foundations of the modern robotics industry. Devol sold the first Unimate to General Motors in 1960, and it was installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die casting machine and stack them. Devol's patent for the first digitally operated programmable robotic arm represents the foundation of the modern robotics industry.

The first palletizing robot was introduced in 1963 by the Fuji Yusoki Kogyo Company. In 1973, a robot with six electromechanically driven axes was patented by KUKA robotics in Germany, and the programmable universal manipulation arm was invented by Victor Scheinman in 1976, and the design was sold to Unimation.

Commercial and industrial robots are now in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial good**s.**

Robot without a skeleton inspired by squid crawls on land. By this point, soft 3D-printed robots have a bit of a history. Early versions were typically powered by compressed air fed into them through tubes, which caused different parts of their bodies to flex. Generation of the compressed air took place outside the robot, as did the control over which parts of the robot received it. Still, these robots demonstrated potential, as they were able to squeeze through narrow cracks by flexing carefully. A later version also allowed these robots to change colour.

Octobot: It was designed in 2016 by researchers at Harvard University

A team at Harvard University researchers with expertise in 3-D printing, mechanical engineering, and microfluidics has demonstrated the first autonomous, untethered, entirely soft robot— actually about 300 of them, since they are so cheap to make — that is opposite of the common view of a robot. It is soft, not hard. It is flexible not rigid. It's neither mechanical, nor electrical. It's powered by fluids. This small, 3-D-printed robot — nicknamed the "Octobot" — could pave the way for a new generation of such machines.

Idea of making Octobot: The idea is to make this something that is powered by a chemical reaction in fluids; fluid movement moves the arms and directs the robot's actions. It can be printed cheaply by the 3-D printer with the most costly part a really small bit of platinum. Aside from that it is essentially like bathroom caulk, "a rubbery-type object," Lewis said.

"It's sort of a hybrid between octopus and robot," said study author Jennifer Lewis, a Harvard professor of biologically inspired engineering. "We've done something that nobody's been able to do."

Soft robots are important because "you've got these hard mechanical objects and soft humans" and when they interact, or collide, it can be a problem, Lewis said. That's not the painful case with Octobot, which fits in the palm of a hand. It's softer and more adaptive, she said.

Lewis said, "all Octobot can do is wiggling a bit. It can't really even move along a table yet", so this is an "extremely simple first step". Initially it was supposed to be a spider, but the team wanted both swimming and crawling and it looked more and octopus is considered.

Outside robotic experts raved about the new squishy machine. In an email, Tufts University professor Barry Trimmer called it "an ingenious approach to building and controlling a completely soft robot." Daniela Rus at MIT said the discovery was what the soft robotics community has been looking for: "The octopus robot is a first self-contained soft robot system whose components are all soft — it is a very beautiful machine."

Components, features and working of Octobots

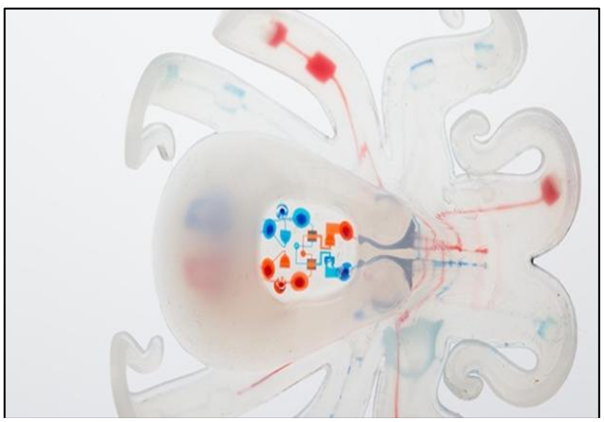
Components and Features: Soft robots possess many attributes that are difficult, if not impossible, to achieve with conventional robots composed of rigid materials. Soft robots must still be tethered to hard robotic control systems and power sources. New strategies for creating completely soft robots, including soft analogues of these crucial components, are needed to realize their full potential. The untethered operation of a robot composed solely of soft materials. The robot is controlled with microfluidic logic that autonomously regulates fluid flow and, hence, catalytic decomposition of an on-board monopropellant fuel supply. Gas generated from the fuel decomposition inflates fluidic networks downstream of the reaction sites, resulting in actuation. The body and microfluidic logic of the robot are fabricated using moulding and soft lithography, respectively, and the pneumatic actuator networks, on-board fuel reservoirs and catalytic reaction chambers needed for movement are patterned within the body via a multi-material, embedded 3D printing technique. The fluidic and elastomeric architectures required for function span several orders of magnitude from the micro scale to the macro scale. Our integrated design and rapid fabrication approach enables the programmable assembly of multiple materials within this architecture, laying the foundation for completely soft, autonomous robots.

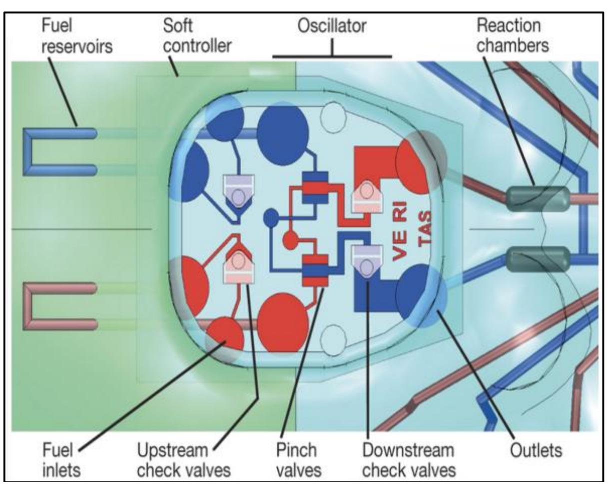
Working: Soft robots can move without batteries. The Octobot has eight arms that are pneumatically driven by steady streams of oxygen gas. This gas is given off by liquid hydrogen peroxide fuel after it chemically reacts with platinum catalysts.

The 0.2-ounce (6 grams) robot is controlled using tiny 3D-printed networks of plumbing. Whereas conventional microelectronic circuits shuffle electrons around wires, scientists have begun developing microfluidic circuitry that can shuffle fluids around pipes. These devices can theoretically perform any operation a regular electronic microchip can, previous research suggested.

The Octobot's microfluidic controller is filled with the liquid hydrogen peroxide fuel. The fuel undergoes a chemical reaction on board as well, rather than in an external combustion chamber. The fuel doesn't combust at all; it's a solution of hydrogen peroxide in water, something you might find in your medicine cabinet. When in contact with a platinum catalyst, this chemical (formula: H_2O_2) forms water and releases oxygen. The oxygen gas is then used to power the robot's movements just as compressed air was in the earlier robot. As the fuel gives off oxygen, pressure from the gas builds up in the controller and eventually causes some valves to open and others to close, inflating chambers in half the robot's arms and forcing them to move. Pressurized gas then builds up once more, triggering valve openings and closures that make the other robot's arms move.

It needs hard work to avoid having combustion take place. They ended up using a solution that's 50-percent hydrogen peroxide, even though it's possible to obtain higher concentrations. The reason to use this concentration is that "concentrations above 50% [by weight] drastically increase the decomposition temperature, resulting in combustion within the printed catalytic reaction chambers." In other words, higher concentrations set the robot on fire while feeding it a steady supply of oxygen.





To provide controlled movement, a series of valves determines where the fuel gets sent, as different reaction chambers sent oxygen gas to different Octobot arms. Once there, the gas inflated a chamber, causing the arm to flex. A valve allowed the gas to slowly drain out, allowing the arm to return to a relaxed configuration. Right now, this just raises and lowers the arms, though it's conceivable that with a slightly different geometry the arms could move Octobot around.

The control mechanism is actually a simple series of valves with feedbacks. When one set of valves is open, it pinches off the fuel supply of the second. The feedback eventually flips this so that the fuel supply oscillates between feeding two reaction chambers.

The Octobot can only wave its arms. "Integrated sensors would also allow reaction to the bot's environment".

There is no on-off switch for this current version of the Octobot — it activates once it gets filled with fuel. Future bots with more complex controllers and sensors could be envisioned with on-off switches.

The Octobot can currently run for about 4 to 8 minutes. The researchers said they can probably improve the bot's run-time using more sophisticated designs that better control how the fuel is used.

"We foresee soft robots expanding the role of robots in human-populated environments — human-robot interaction".

In addition, "a separate but very interesting potential application for this type of robot is in high-risk, dangerous areas such as search and rescue". "The total material cost for the Octobot is just over $2, and fuel costs approximately 5 cents per fill. One could envision a scenario in which 100 bots are deployed to investigate a scene, anticipating that 80 would be destroyed."

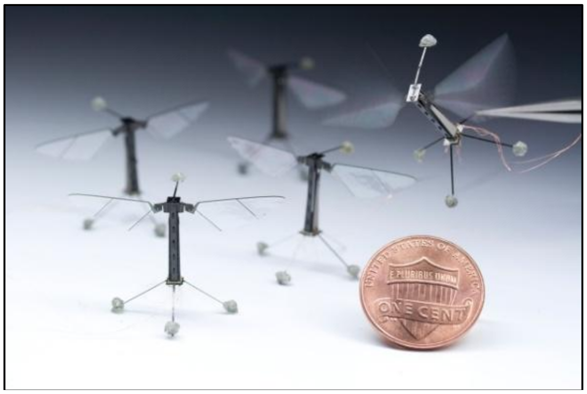
How to get rid of the need for an external power supply

By sacrificing a bit of flexibility, they added a small butane tank that allowed the robot to make explosive leaps when a chamber full of butane was lit. The partially rigid structure also enabled them to place the controller on board.

Conventional robots vs. soft robots

- Conventional robots are made up of rigid parts while soft robots are made up of soft, elastic plastic and rubber.
- Conventional robots are vulnerable while Octobots are non-vulnerable.
- Unlike conventional robots, the Octobot is pliable. It has no rigid parts whatsoever — no batteries, no circuit boards, no electronics. Instead, the entire robot is 3D-printed out of silicone rubber.
- The 0.2-ounce (6 grams) robot is controlled using tiny 3D-printed networks of plumbing. Whereas conventional microelectronic circuits shuffle electrons around wires.
- Soft robots are comparatively more resistance to damage as compared to conventional robots.
- Octobots do not have electrical circuit. These do not need any mechanical processes like other robots.
- It is powered by hydrogen peroxide which starts as a liquid and then turns into a gas while conventional robots are powered by batteries.
- Soft robots can adapt more easily to some environments than rigid machines, and this research could lead to autonomous robots that can sense their surroundings and interact with people.

What other animals have inspired soft robots?
A lot of the early work in soft robotics has been inspired by nature, especially by flexible creatures. So researchers have built robot jellyfish, robot caterpillars and robot fish.
According to MIT researchers, the robot fish is particularly good at escape manoeuvres. Because its body is flexible, the robot fish can change direction in a fraction of a second, which is almost as quickly as a real fish.



Robo Bees
Using bees as a model, researchers at Harvard University have developed so-called 'Robo Bees,' which are about the size of a penny.
These soft robots are actually part of a broader trend called "bio-inspired design." It includes soft robots, like the Octobot, and also flying and crawling robots, inspired by insects.

Cockroach-inspired robots designed for disaster search and rescue: Researchers at Harvard have **built flying robot bees about the size of a penny**. And they've also built crawling robots, inspired by insects. Most of these are proof-of-concept designs, but they point toward one possible direction for robots of the future.

Bee-sized drones use static electricity to perch like bats
What challenges do soft robots face?
Ryan Truby researched on Octobots and said that conventional robot parts — like batteries, circuit boards and sensors — are still used because they work pretty well. So the challenge for soft robots is finding viable alternatives. "We're a bit off still from seeing really cool, entirely soft systems, like the Octobot, that are going to be able to sense their environment and move and react to stimuli," The next steps forward are not entirely soft systems, but almost entirely soft systems". So the future may be robots that combine the best parts of both approaches — hard and soft.

When might we start to see soft robots in use?
Soft robotics is still an emerging field, and a lot of the work that's being done is still at the research level. That said, we're starting to see elements of soft robotics starting to make their way out of the lab. For instance, some underwater robots now use soft grippers when they're at the bottom of the ocean so they can explore coral, and do scientific work without harming the environment.

Fingerless robot 'hand' grips almost anything
Wehner and Truby believe those types of soft grippers are the next step in commercializing this kind of robotics. Again, this becomes especially important when robots are working closely alongside humans. There's a safety issue there. They hope the work they're doing will lead to more human-robot interaction — though I'm not sure if I'm ready to let a soft robotic medical worm crawl around inside me quite yet.
What are the advantages of soft robots?
- Soft robots are particularly well-suited to tasks that require a very light touch — like picking up an egg.
- It could either handle something that's very delicate, or move the body around to get into tight spaces in search and rescue, or maybe internal medicine. Something that's soft like an earthworm could crawl through the body better than something that's rigid, like a crab.
- Soft robot medical worms can crawl around inside your body easily.
- Soft robot made of silicone has the potential to be a lot safer.

Conclusion
Octobot is completely self-contained; it doesn't need any external power source or rigid internal components. While the current generation of industrial robots is primarily made of metal, the research community has been getting interested in the potential for soft-bodied robots. These have a number of advantages, such as being easy to customize via 3D printing and providing a flexibility that lets them squeeze through tight spaces. These do not harm because of the soft body. Octobots are flexible and these do not require any metal. These are user friendly because of the soft body. In today's issue of *Nature*, the creation of a soft-bodied robot that carries its own fuel supply, which powers the robot through an on-board chemical reaction. Soft, flexible on-board logic then directs the reaction products to control the movement of the robot.

Future Aspects
Many of the research demonstrations created so far, however, have required some compromises. For some iterations, this has meant the control hardware and power sources have been kept separate, connected to the robot via a tether. For other attempts, this has meant the final product is a mixture of hard and soft pieces. While the result is pretty limited in what it can do, its creators make up for that with a certain cool factor, making their creation look a lot like an octopus. As the field of soft robotics continues to rapidly expand, it will allow the field to rapidly move forward in a whole new direction."

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