CRJ R&D: Robots that self-assemble

This issue, our regular section curated by **Ian Portelli** brings details of tiny, intricate robots that unfold themselves, bringing immense future potential to all manner of emergency situations

During a crisis or in natural disaster conditions, responders are often presented with serious risks when working directly at the emergency site, owing to fire, excessive heat, flooding or limited access. Such hostile conditions can also hamper the provision of medical or crisis relief, as well as complicating efforts to restore the area to a safe and habitable state. Recent discoveries in small robot applications have led to multiple robotic prototypes that can work in extreme conditions, such as high temperatures, within water and even when ingested into the body. These robots have potential for both medical applications and in crisis response, especially where the usual protocols and procedures are limited by the surrounding environment and circumstances.

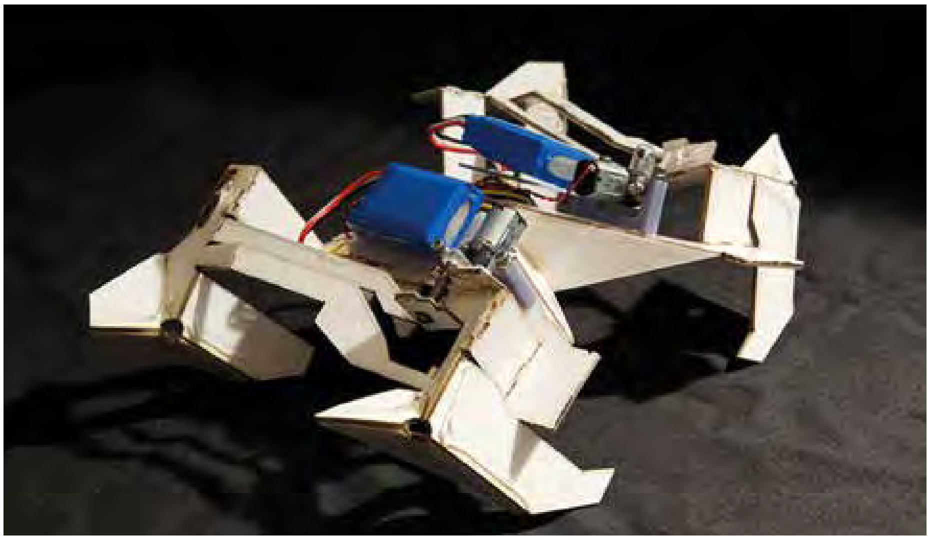
The bakeable robot, as its name infers, assembles itself when extreme heat is applied to it. Because they can perform and complete tasks safely without degrading, such robots could potentially operate in environments that are hazardous for human responders.

The basic structure of the devices, also nicknamed 'origami robots' because of their folding abilities, is pre-printed and then mapped out so that when heat is administered, they fold into their three-dimensional form and are ready to move. Pre-cut slits in the material (composed of a sheet of polyvinyl chloride between two sheets of sturdy polyester) allow the structure to be manipulated to the desired result after heat has been administered.

Given that they are so small and intricate, the robots have the potential to act as surgical tools or even give biopotential feedback when wired with specific sensors.

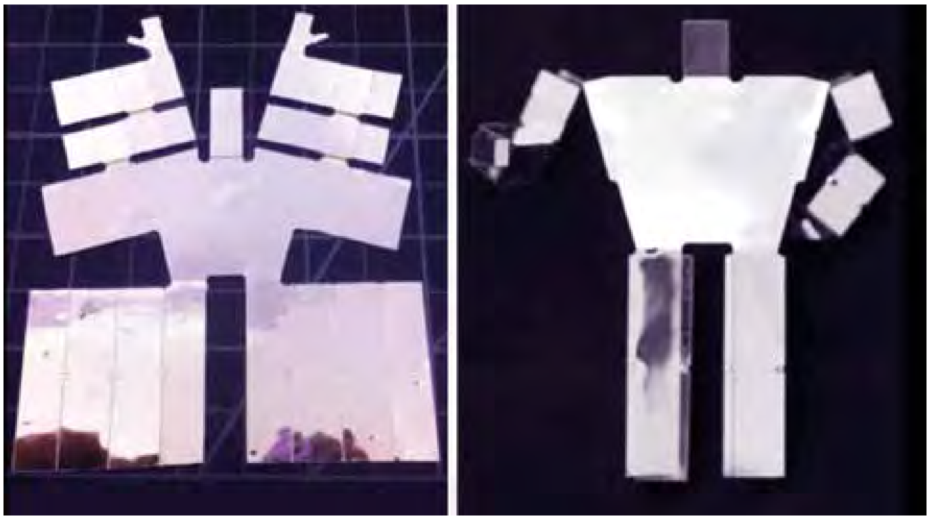
Researchers and electrical engineers Erik Demaine and Daniela Rus from MIT and Harvard, along with colleagues from the University of Sheffield, the University of Zurich, and the Tokyo Institute of Technology, discovered that applying heat directly through electrical components rather than using environmental heat, opens up even more potential applications for these robots. A layer of electrical leads within the multi-layer composition of the robot provides external heat, allowing responders to control it from a distance or via signals. This means that instead of just folding to assemble itself, more complex actions like self-walking can be achieved, and folding patterns can occur in a sequence rather than happening all at once, making these robots more able to interact with their surrounding environment or to complete tasks.

The experimental robot created by these researchers contains two motors linked by a microprocessor that guide the robot's legs to move and bear weight, permitting a degree of freedom that



The self-folding mobile prototype developed by researchers at MIT and Harvard: These robots have potential for both medical applications and in crisis response, especially where the usual protocols and procedures are limited by the surrounding environment and circumstances

Harvard's Wyss Institute



The bakeable robot as its name infers, assembles itself when extreme heat is applied to it; the basic structure is pre-printed and mapped out so that when it is heated, it folds into its three-dimensional form

Melanie Gonick | CSAIL | MIT

initiates the robot to move mechanically in response to the motor.

The design can be manufactured at a low cost and, thanks to its lightweight structure, can enter areas unsuitable for human work and perform small tasks such as moving debris or carrying supplies. In the future, they might be used for photographing disaster sites.

Currently, these origami robots are relatively small, but can bear loads twice their weight, which means that bigger ones have the potential for larger applications. In addition, the bakeable robots can move over rough terrain and up steep hills, and are so lightweight that they can skim a liquid surface, making them a potential asset in flooding incidents. A video of the origami bakeable robot released by MIT shows it smoothly skimming over water, fluttering up a ramp, and walking over a regular smooth surface. In the video, Rus enthusiastically explains how the robot can clear obstacles, swim, carry objects and is recyclable at the end of its life cycle.

Another type of device, the ingestible robot, is swallowed via a biodegradable capsule (made of ice or other organic material) and is activated via biological interaction with stomach fluid. Researchers at the Tokyo Institute of Technology and the University of Sheffield discovered that the gastric liquid initiates a folding process after which the ingestible robot can then be steered by external magnetic fields. The robot is designed so that it relies upon rotational motion for movement and steering within the stomach or lower intestines, propelled by stick-slip action and force distribution coming from the surrounding body.

The medicinal applications of these particular robots are vast and unexplored; they could potentially be used for retrieving unwanted swallowed objects or even for internal wound care. They could even double as a type of manual drug-delivery system.

The utilisation of these robots requires manual manipulation of the small capsules with magnets outside the body, thus requiring the need for close operator contact. Using them in remote areas or to replace invasive clinical procedures could cut down on the need for expensive equipment, or be useful when the necessary tools and environment to perform a regular surgery or invasive procedure are not optimal.

The designs are simple and pose little biological threat; after having performed their desired function, the robots biodegrade within the body. Their operation does not require extensive clinical staff support as would be the case in a surgery, making them promising for rural areas where medical facilities and equipment are scarce.

Rus is the director of a group at MIT called the Computer Science and Artificial Intelligence Laboratory (CSAIL), which lists the self-assembling robot under the 'artificial intelligence' section of its website, as hopefully these robots will soon be able to think and move for themselves, based on algorithms implemented by the researchers.

Rus has carried out previous studies focusing primarily on robot navigation and spatial recognition. In these studies, she discusses several distinct algorithms that allow robots to move around obstacles based on a task pre-programmed into its controls. Sensors are implanted into a study space where the robot operates to manipulate its movements during its journey from start to finish. Numerous, inexpensive sensors used in trial research studies were placed in an environment to guide the robot to its desired endpoint. Feedback properties, based on the placement of the sensors and the proximity of the robot, allow the user to manipulate the robot continually as it moves through its course. Primarily, these movements are lattice-based, meaning they have geometric properties when it comes to combatting, manipulating and overcoming obstacles.

However, the experiments took this into consideration and considered each unit as an 'atom' in that they are separately autonomous so they can function either independently or in conjunction with other atoms. The teamwork of the geometric atoms working together initiates more complex movement within a spatial environment, which is beneficial for approaching different types of terrain or environments that involve site-specific movement, as we would see either in the body or in specific disaster zones.

When the type of environment these robots will be introduced to is known beforehand, engineers programming them would be able to plan accordingly so that the robots' atoms could assemble over any specific obstacles. This movement, although promising, may still need further progression before it can be entirely implemented with the ingestible and bakeable robots, being that they are more intricate and complex devices.

Vast array of applications

Currently, Rus's work does not merge both concepts – ie the self-assembling robot and the spatial planning algorithms. However, she says the team would like to do in vivo experiments next, and is currently working on applying sensors to the robot so that it can be controlled without an external magnetic field.

"The robot can remove foreign objects, it can patch wounds, or it can deliver medicine at designated locations," says Rus in an online video provided by Melanie Gonick at MIT. This means that these 'designated locations' are pre-planned and have been analysed via code to allow the robots to find the site of the problem, fix it and exit the body.

With humans manipulating these robots they will continue to evolve, offering highly versatile and sophisticated functions that can be deployed in a variety of disciplines. Robots that can make their own decisions via algorithms and planning, and not be driven by a pre-programmed external magnetic field, could open the door to a vast array of applications for disaster relief and crisis response. C›RJ

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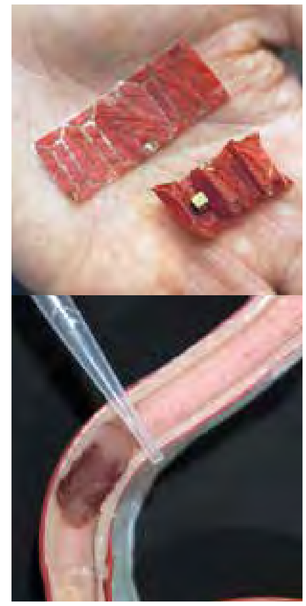

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