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Nuptials notice: foods and robots are getting married

Edible electronics are being developed to assist rescue operations and go inside hospital patients, setting the stage for all-consuming tech to become consumable.

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Professor Dario Floreano is a Swiss-Italian roboticist and engineer engaged in a bold research venture: the creation of edible robots and digestible electronics.

However counterintuitive it may seem, combining food science and robotic science could yield enormous benefits. These range from airlifts of food to advanced health monitoring.

Boundary breaking

'Our goal is to start replacing electronic parts by edible components,' said Floreano, who is director of the Laboratory of Intelligent Systems at the Swiss Federal Institute of Technology in Lausanne.

He leads a project that received EU funding to push the boundaries of robotics research by creating robots that can be eaten and foods that behave like robots.

Called ROBOFOOD, the four-year project is scheduled to run through September 2025. The team includes researchers from Switzerland, Italy, the Netherlands and the UK.

Floreano dates the start of his interest in the idea of marrying food and robotics to a throw-away comment made in 2017 by a postdoctoral researcher emerging from a weekly laboratory meeting in Lausanne.

The researcher – Jun Shintake – observed that the main difference between robots and living systems is that robots can't be eaten by other life forms.

Floreano got to thinking about possible ways to change that.

Flying cakes

The ROBOFOOD team has already built a drone with wings of rice cakes that are glued together with edible oils and chocolate. The feat was achieved in collaboration with Wageningen University in the Netherlands.

‘We came up with the first drone where 50% of its mass was edible,’ said Floreano.

The researchers were inspired by the notion that drones deployed in emergency rescues might not only locate lost people – or animals – and even deliver vital medicine or food but also act as nutrition themselves.

Floreano said the edible components of the ROBOFOOD drone were sufficient to meet United Nations standards for food needs in a crisis.

‘These parts delivered the nutrition recommended by the UN for those in emergency situations,’ he said.

The challenge here is to build wings from edible materials that are robust enough to hold up in wind, rain and high temperatures.

Gut sensors

Extending the concept to health, the project researchers have also produced edible electronics that could help treat or monitor illnesses of the gut.

In collaboration with a robotics expert at the University of Bristol in the UK, Professor Jonathan Rossiter, the team has developed digestible sensors that – unlike current devices for the gut – don’t need to be excreted by or recovered from the patient.

The digestible sensors avoid the risk of materials remaining in the body.

While further testing and development are needed, the sensors signal the feasibility of building digestible machine parts.

Eat-it-all goal

In yet another breakthrough, the project has developed an edible version of the component that makes a robot able to function.

The component, known as the actuator, is the part of the machine that helps it to achieve physical movements by converting energy into mechanical force.

In other words, it’s the part that would enable the robot to do something useful once a person has swallowed it.

In that context, the ROBOFOOD edible machine part marks a big step ahead on the road towards robots that are both fully functional and edible.

Search for switches

An added benefit of this whole research direction is environmental. Food-grade materials and processes that can easily be broken down or even digested would help tackle the world’s growing amounts of electronic waste.

One partner in ROBOFOOD is an electronics engineer named Dr Mario Caironi, a senior researcher at the Italian Institute of Technology in Genoa.

Caironi has been coming to grips with the main challenge in creating edible technology: replacing everyday electronics with things that people can digest.

‘We started off by looking for materials that are edible, mostly derived from foods, to make electronic devices,’ he said.

Caironi sketched out a futuristic view of edible electronics in a paper published in 2020.

He has drawn inspiration from a classic science-fiction book called “Fantastic Voyage” by the late American writer Isaac Asimov.

In the book, four men and a woman are reduced to a microscopic fraction of their original sizes and sent in a miniaturised submarine through a comatose man’s carotid artery to destroy a blood clot in his brain.

Battery breakthrough

Besides his role in ROBOFOOD, Caironi leads separate EU-funded research into “electronic food”.

Called ELFO, the five-year project runs through August 2025 and is designing edible electronic systems for health purposes.

In March 2023, the ELFO team revealed the first-ever rechargeable edible battery. For certain applications such as food sensors, the battery could be re-used rather than thrown away.

It was made of common food ingredients and dietary supplements wrapped in beeswax. The battery could operate for around 10 minutes, bolstering hopes that more advanced versions could power medical devices swallowed by patients.

Caironi had spoken with medical doctors in Italy about their wish to give patients a safe edible electronic device that, after being swallowed, could diagnose or treat a condition in their gut.

Natural transistors

The ELFO scientists have scoured the scientific literature to find edible materials suitable as insulators, conductors and semiconductors – all needed to make electronic circuits.

The group has found that gold-leaf material used by some chefs can serve as wiring for edible devices, while honey can be used as a natural semiconductor.

Semiconductors are needed for transistors, which are crucial cogs in any circuit.

Other semiconductor candidates in nature include dyes and pigments, according to Caironi.

As an example, he said that beta-carotene – a red-orange pigment abundant in carrot, pumpkin, sweet potato and mango – is a reasonably good natural semiconductor if processed correctly and is edible.

Big ambitions and rewards

The ELFO group is putting together as much edible material as possible to make a battery-powered pill that would give out an electronic signal and could be tracked as it moves through a patient’s gut.

The pill could, for example, be instructed to deliver a drug upon arriving at a specific location in the gut.

The plan for researchers in this field is to continue making edible components and to bring them together in electronic devices. That way these devices will contain more and more digestible components.

Back in Switzerland, Floreano’s team is printing a label for each robot indicating its nutritional profile and percentage of edible parts.

With such steps, a scenario in which a lost and hungry mountain hiker receives a rescue drone labelled 100% edible no longer belongs solely to the sci-fi realm.

‘We are searching for problems where we think we can provide a solution,’ said Floreano. ‘We want to take high risks to try to get high rewards if we succeed.’

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