Storing data in everyday objects

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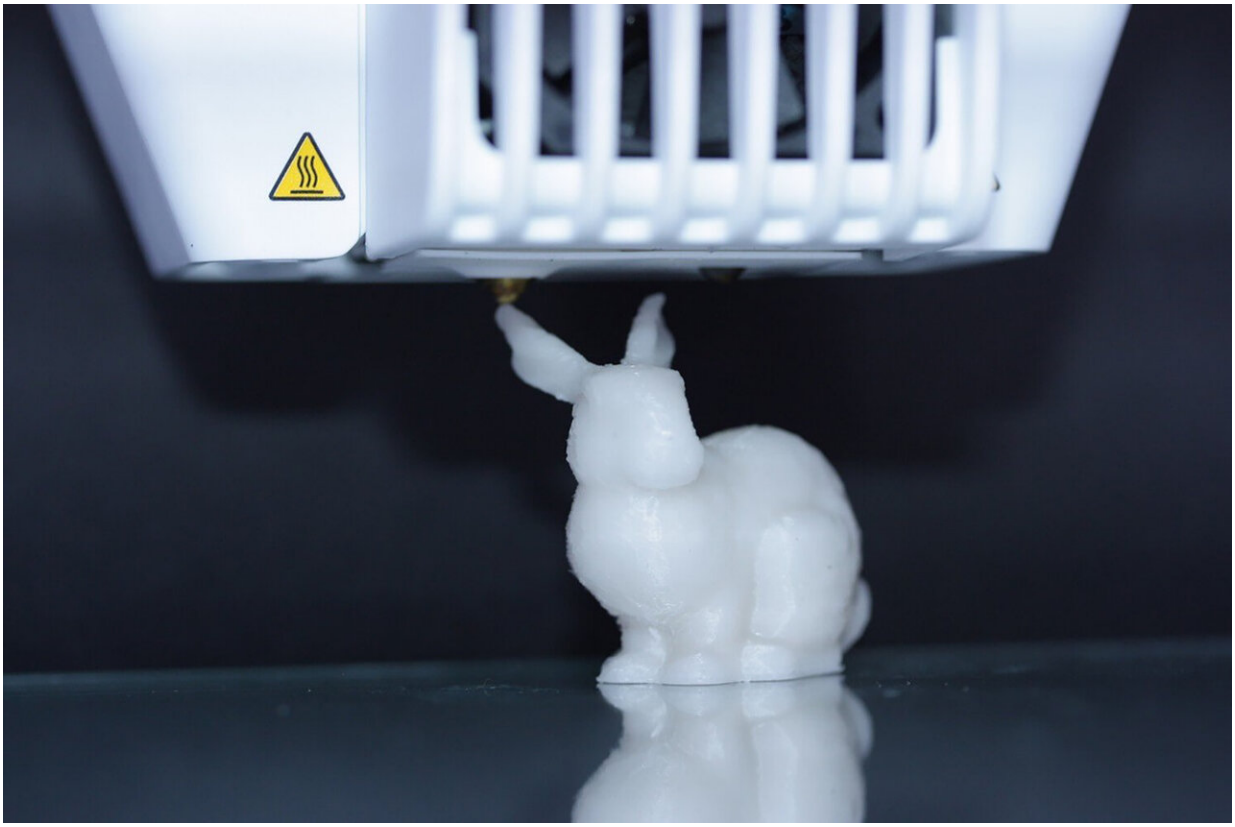

A 3D-printed plastic rabbit. The plastic contains DNA molecules in which the printing instructions have been encoded. Credit: ETH Zurich / Julian Koch

Life's assembly and operating instructions are in the form of DNA. That's not the case with inanimate objects: anyone wishing to 3-D print an object also requires a set of instructions. If they then choose to print that same object again years later, they need access to the original digital

information. The object itself does not store the printing instructions.

Researchers at ETH Zurich have now collaborated with an Israeli scientist to develop a means of storing extensive information in almost any object. "With this method, we can integrate 3-D-printing instructions into an object so that after decades, or even centuries, it will be possible to obtain those instructions directly from the object itself," explains Robert Grass, Professor at the Department of Chemistry and Applied Biosciences.

Several developments of the past few years have made this advance possible. One of them is Grass' method for marking products with a DNA "barcode" embedded in miniscule glass beads. These nanobeads are used in industry as tracers for geological tests or as markers for high-quality food products, thus distinguishing them from counterfeits using a relatively short barcode consisting of a 100-bit code. This technology has now been commercialized by ETH spin-off Haelixa.

It has become possible to store enormous data volumes in DNA. Grass's colleague Yaniv Erlich, an Israeli computer scientist, developed a method that theoretically makes it possible to store 215,000 terabytes of data in a single gram of DNA. And Grass himself was able to store an entire music album in DNA—the equivalent of 15 megabytes of data.

The two scientists have now wedded these methods into a new form of data storage, as they report in the journal *Nature Biotechnology*. They call the storage form DNA of Things, a takeoff on the so-called Internet of Things, in which objects are connected with information via the internet.

Comparable to biology

As a use case, the researchers 3-D printed a rabbit out of plastic that contains the instructions (about 100 kilobytes' worth of data) for printing

the object. The researchers achieved this by adding tiny glass beads containing DNA to the plastic. "Just like real rabbits, our rabbit also carries its own blueprint," Grass says.

And just like in biology, this new technological method retains the information over several generations—a feature the scientists demonstrated by retrieving the printing instructions from a small part of the rabbit and using them to print a whole new one. They were able to repeat this process five times, essentially creating the "great-great-great-grandchild" of the original rabbit.

"All other known forms of storage have a fixed geometry: A hard drive has to look like a hard drive, a CD like a CD. You can't change the form without losing information," Erlich says. "DNA is currently the only data storage medium that can also exist as a liquid, which allows us to insert it into objects of any shape."

Hiding information

A further application of the technology would be to conceal information in everyday objects, a technique experts refer to as steganography. To showcase this application, the scientists turned to history: Among the scant documents that attest to life in the Warsaw Ghetto during World War II is a secret archive that was assembled by a Jewish historian and ghetto resident at that time and hidden from Hitler's troops in milk cans. Today, this archive is listed on UNESCO's Memory of the World Register.

Grass, Erlich and their colleagues used the technology to store a short film about this archive (1.4 megabytes) in glass beads, which they then poured into the lenses of ordinary glasses. "It would be no problem to take a pair of glasses like this through airport security and thus transport information from one place to another undetected," Erlich says. In

theory, it should be possible to hide the glass beads in any plastic objects that do not reach too high a temperature during the manufacturing process. Such plastics include epoxides, polyester, polyurethane and silicone.

Marking medications and construction materials

Furthermore, this technology could be used to mark medications or construction materials such as adhesives or paints. Information about their quality could be stored directly in the medication or material itself, Grass explains. This means medical supervisory authorities could read test results from production quality control directly from the product. And in buildings, for example, workers doing renovations can find out which products from which manufacturers were used in the original structure.

At the moment, the method is still relatively expensive. Translating a 3-D-printing file like the one stored in the plastic rabbit's DNA costs around 2,000 Swiss francs, Grass says. A large sum of that goes towards synthesizing the corresponding DNA molecules. However, the larger the batch size of objects, the lower the unit cost.

More information: A DNA-of-things storage architecture to create materials with embedded memory, *Nature Biotechnology* (2019). DOI: 10.1038/s41587-019-0356-z , www.nature.com/articles/s41587-019-0356-z

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