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The Chemical Computer—Chemputer™

The 1960's TV show Star Trek included many sci-fi props that actually exist today. One of the most fascinating was the starship's replicator that could create complex solid objects, liquids, and anything else one would want instantly upon verbal request.

How the chemical formulas and building plans that were necessary to produce all the different substances and products were stored was left to the viewer's imagination. Development of a true replicator as powerful as Star Trek's is happening in three stages. Stage one was the development of 3D printing. My April 2019 column shows how 3D printing is now changing how solid objects are being made (www.omagdigital.com/publication/?i=577145&ver=html5&p=10).

Stage two is the development of the Chemputer™, described here, and the third stage is currently under development by the US Defense Advanced Research Project Agency (DARPA) and BAE Systems. BAE systems is a huge British multinational aerospace company that is now working to combine the Chemputer and 3D printing into an entirely new printing technology that can create solids, complex liquids, and even complex machines. First you need to learn about the Chemputer which is one of the foundations of what is to come.

Professor Leroy Cronin, the Regius Chair of Chemistry at Glasgow University in Glasgow, UK, and his team have developed a Chemputer that automatically produces complex molecules without human intervention. His vision was to take the 3D printing concept of building objects from a digital file in a new direction where the building hardware produces controlled chemical reactions to create complex molecules. His team's goal is the development of a chemistry 3D printer that can produce medications on demand where they are needed. This technology could allow off-patent medications to be produced in medical clinics around the world and thereby bring life saving cures to people in third world countries where doctors and medicines are in short supply.

Professor Cronin and his team's achievement was summarized in the title of their research paper "A programmable chemical computer with memory and pattern recognition." This research paper was written for scientists; I expect that part of my readership, which includes professors, as well as teachers and students, might want to read the full document. The scientific paper was published, in a downloadable pdf format on February 13, 2019, on the ChemRxiv™ website. You can download it at https://chemrxiv.org/articles/A_programmable_chemical_computer_with_memory_and_pattern_recognition/7712564.

Photos courtesy Cronin Group, University of Glasgow, UK

Photo 1—The Chemputer is an automated chemistry printer under the control of an AI self-learning program imbued with the knowledge of a team of chemical engineers.

Their Chemputer, a programmable chemistry laboratory in a box (Photo 1), has automated systems that can follow the directions given to it by its central computer. It runs an artificial intelligence machine learning program that controls and also monitors the chemical reactions that it is performing as it creates complex molecules. To do this monitoring it uses sensors and a digital camera to observe and provide feedback to its CPU. It uses this information to anaxlyze and control each step of the chemical process it is performing. Basically the Chemputer is an AI automated system that can perform the same tasks that are currently being performed by highly trained chemists.

When a step-by-step procedure is initiated by chemists, they carefully combine different molecules using the appropriate hardware to guarantee that the output of the chemical reaction is always the same. The Chemputer has been imbued with the knowledge of that highly trained chemist. The hardware used by the chemist would depend on the complexity of the experiment, but might include oscillators, stirrers, and measuring equipment.

The Chemputer has a number of cells where different chemicals can be automatically added following the directions of the program. The cells are switchable and the operations that would normally be performed by a chemist, to create the chemical reaction, are all handled automatically by the machine using magnetic stirrers and oscillators. The Chemputer also has the measuring equipment

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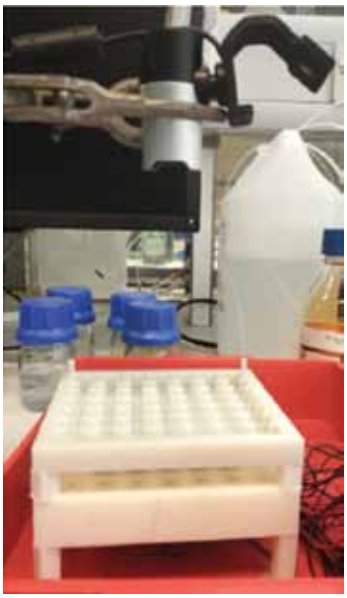
Alan Pierce, Ed.D., CSIT, is a technology education consultant. Visit www.technologytoday.us for past columns and teacher resources.



Photos 2 and 3—The digital camera is positioned so it can observe and provide feedback to the AI program that is running the system.

and sensors needed to determine that the system is performing the tasks necessary to produce the desired outcomes.

In the Chemputer the chemist's eyes have been replaced by a digital camera (Photos 2 and 3), which feeds its video to the AI machine learning program for analysis. So, instead of a chemist feeding his or her data into a computer for data analysis after an experiment is completed, the Chemputer combines the experiment and analysis into one artificially intelligent system. This system can perform thousands of calculations a second while the combining processes are ongoing. You can see the first generation Chemputer in action at: https://www.youtube.com/watch?v=WvEkm7ZBKSc

The US Defense Advanced Research Project Agency (DARPA) is currently funding Molecular Informatics research to explore chemistry's "untapped, rich palette of molecular diversity…outside of traditional digital logic-based approaches," a direction which could take current replicator technology to the next level.

BAE Systems, a British multinational aerospace company with 85,800 employees in 40 different countries, has partnered with Glasgow University to take the breakthroughs of 3D printing solids and the Chemputer to the next level. They are working on the development of a printer that would use the molecular processing of the Chemputer to produce complex machines. "A radical new machine called a Chemputer™ could enable advanced chemical processes to grow aircraft and some of their complex electronic systems, conceivably from a molecular level upwards" (BAE Systems). They are working on creating a replicator that builds using Chemputer molecular processing. This printer would actually match the building ability, although at a much slower speed than the Star Trek replicator.

How close they have come to achieving what they show in this video, released in July 2016, is now probably marked top secret: https://www.youtube.com/watch?time_continue=1&v=EKt_zQHQ-0k.

Taking it a Step Further

1. Star Trek, Avengers, other TV shows, and video games show technologies that were science fiction when the shows or games were created. Your challenge is to research past and current movies, games, and TV shows to find technologies that were once science fiction but now exist.

2. Document the technologies by collecting Internet photos that show the props next to the working items that now exist.

3. Many sci-fi props are still science fiction. List the ones you find most interesting and explain why you feel they will or won't ever become reality. td