

3D Printing and Humanity's First Imperfect Replicator

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Abstract

A personal account is given of the RepRap Project by the person who instigated it. RepRap is an open source project carried out by volunteers worldwide to design and to build a self-replicating 3D printer. The influence of early rapid-prototyping developments is outlined, as are biomimetic ideas from evolutionary theory. Finally the large (though uncertain) number of RepRaps in the world is mentioned, as is the impact that the project has had on its instigator.

Of all the delights of 3D printing, perhaps the most delightful is that its first public appearance was as a joke. In 1971, Wyn Kelly Swainson filed the patent¹ for what was to become stereolithography, but the patent wasn't published until years later. Meanwhile, in a copy of the *New Scientist* in 1974,² David Jones put forward the idea of using a laser to cause a liquid monomer to polymerize in the path of the beam and of steering the beam using a computer to solidify a real three-dimensional object where none had been before.

Jones's column trod a humorous path between what was just-about possible and what was exquisitely fantastic—great light boats that floated on the interface between the tops of clouds and the clear sky above; a democratic bus in which every passenger had a steering wheel and the bus went wherever the average pointed; a molecular ball bearing in the form of a 60-atom carbon polyhedron. Sometimes—as with the fullerenes—his prescient inventiveness was formidable, and

what seemed initially to be agreeably risible later turned into sturdy science or engineering. So it was with 3D printing.

I was a research student when Jones's laser polymerization idea appeared. I thought at the time that it might be one of his jokes that would actually work, and a decade later as a junior academic I started to see rapid prototyping machines appear. I was intrigued but disinterested—I was working on computational geometry at the time. However, just after the turn of this century the British government gave my university a large equipment grant, and I was entrusted with spending some of it. I bought a Stratasys Dimension and a 3D Systems Vanguard.

They were a glorious liberation.

I hope that I will not be accused of immodesty if I say that I am a competent machinist. Given a lathe or a mill—either manual or Computer Numerical Control (CNC)—I can

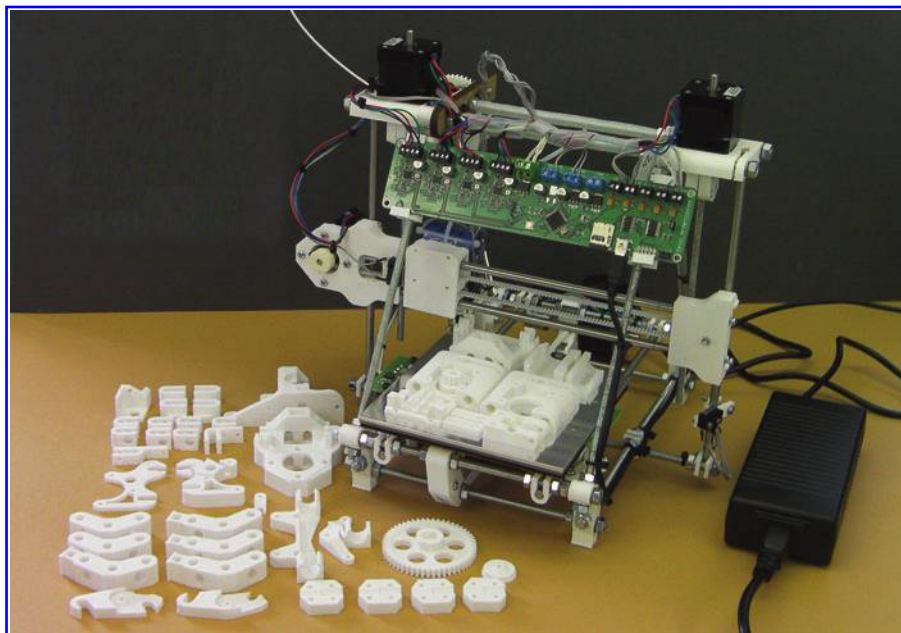
make pretty much anything I want. However the transition from Computer Aided Design (CAD) program to a finished object is often fraught, even with the most sophisticated and automatic of Computer Aided Manufacturing (CAM) systems.

But with the 3D printers suddenly I could design something and have it in my hand an hour later with no mental or physical effort at all.

The impossible turns into a luxury, then into a necessity, then into a cheap throw-away, and we later tend to forget the extraordinary journey from can't-imagine to have-not to have that the introduction of a really powerful new technology follows. Acquiring a 3D printer felt rather like it would feel to be given a device that fits in your pocket, that gives you access to the whole of human knowledge, and that has the instant ability to connect you to anyone on the planet.

With my university's new machines I set to printing experimental apparatus

¹RepRap Professional Ltd., Bristol, United Kingdom.



RepRap with a full set of its own polymer parts that it has just printed. Photo: Adrian Bowyer.

for the biomimetic inventions and the smart-materials research on which I was working by then. But I also realized that circumstances (in the form of the British taxpayer) had for the first time placed in my control a technology that was so good at making things that it stood a sporting chance of being able to self-replicate. Since childhood I had wanted to make a proper, useful, sustainable self-replicating machine that would reproduce itself out of the laboratory and into the real world.

For some time I had realized that *sustainable*, in the context of self-replication, means what biologists call having an *evolutionarily stable strategy*. This is to say that, to reduce the chances of its becoming extinct, the self-replicator will be caused by evolution to behave in a way that places it at a game-theoretically stable Nash equilibrium among the other self-replicators with which it interacts. Such strategies are an important component of evolutionary fitness.

So, at the beginning of 2004, I started the RepRap Project to build a self-

replicating 3D printer, and I distributed it in a way that I thought would place it at such a Nash equilibrium. Just as the clover does not charge the bee for its pollen, I gave all the RepRap designs and software away free. The clover has evolved to distribute the information in its pollen with the most promiscuous fecundity possible, and so not only does it give the pollen away free, it adds an extra present in the form of nectar. The bee gets a meal, and both species prosper by the resulting mutualistic symbiosis. In the same way I saw RepRap as giving a nectar-like reward to the self-replicating machines that assisted it to reproduce. Those assistant machines are people, and the nectar that RepRap gives them is the goods that the machine makes for them when it is not reproducing itself.

RepRap cannot make all its own parts (just as you cannot make all the amino acids you need). The assistants have to bring extra parts to help, as well as their assembly skill. So RepRap is not a perfect replicator. In this respect, it is just like all living

organisms, which simply have to be good enough to reproduce successfully. There is no perfection in nature.

However, in terms of reproductive fitness, RepRap is doing quite well. There are tens of thousands of RepRap machines out there in the real world, jostling along with their human symbionts, sometimes exasperating and sometimes enchanting.

But always increasing in number.

I have an old friend, and when he and I meet, I sometimes have to break off our conversation. "I must just go out to the workshop," I say. "I need to set the RepRap machines to printing more RepRaps."

"Ha!" he says. "You always said that RepRaps would entice people into helping them to reproduce. And now they have enslaved their very creator to work for them while he deludes himself that they are working for him."

Author Disclosure Statement

No competing financial interests exist.

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