Laurie Wiegler talks to professors Philip Anderson and Cherie Ann Sherman about their ideas for making three-dimensional printing as much of a 'disruptive technology' as downloading music files or toting a digital camera

jumping off the page

NICK SMITH, CAROLYN HERRING

EVER SINCE Johann Guttenberg invented the printing press in 1436 – or since the discovery of moveable clay type in 1041 or even earlier – the world has lusted for ever-greater manifestations of print.

Now, at a time when the Internet is pervasive and newspapers threaten to be replaced by portals worldwide, it's no wonder that two professors at Ramapo College of New Jersey have created a blueprint for the future of 3D printing, a technology that, through a digital conduit, can exploit the World Wide Web.

Physicist Dr Philip Anderson and patent attorney Cherie Ann Sherman together teach the highly popular Invention course at Ramapo's sprawling campus, and it was they who published 'A discussion of new business models for 3D printing' in a recent issue of *Inderscience*. Reaction from the media and fellow students and peers to the paper made it very clear that they had touched a nerve.

RAPID PROTOTYPING

Based on rapid prototyping – the process in which layers build upon themselves before a product or model is born – 3D printing is not actually new. Since the mid-1980s, when Chuck Hull of 3D systems invented them, various versions of the 3D printer have existed.

Today, these expensive, sometimes clunky, devices exist in high school shop rooms, universities, machine shops, and other areas of industry such as pharmaceuticals, entertainment, manufacturing and public safety.

In their *Inderscience* paper, Sherman and Anderson write that: "Rapid prototyping has been referred to as the physical modeling of a design using digitally driven, additive processes and has been primarily used by engineers to fabricate prototypes and models from computer-aided design (CAD) or other digital 3D files. 3D printing is the everyday, office or consumer, version of the rapid prototyping machine."

'The disruptiveness of 3D printing is analogous to the effect that digital cameras had on film – they were convenient, and quickly of equal price and quality'

3D printing builds parts, whether metal or plastic, from CAD drawings that have been sectioned into thousands of layers, offering an alternative to cutting or drilling solid materials. Unlike standard printers, which deposit a 2D layer of ink, the 3D printer lays down epoxy or other substances in what could more accurately be called 'repetitive prototyping'.

DISRUPTIVE TECHNOLOGY

Anderson and Sherman cite Stanford University's David Little, who purported that technology must "first be proven experimentally, justified economically, and then become standardised and affordable before it penetrates the consumer market".

Anderson says: "We think this is similar to digital photography. When [digital cameras] first came out, they were an expensive, low-quality product." Then, "because you could do the downloading of pictures at home, this convenience outweighed low quality and high expense. This is the classic disruptive technology".

In the paper, the authors write that: "We can expect the disruptiveness of 3D printing to be analogous to the effect of digital cameras and colour printers on the film industry; they were convenient and customisable, albeit inferior and more expensive than film, but now their quality and pricing is equal to or superior to film."

Sherman further likened the 3D printer's potential model to another type of technology: "It was amazing how the music industry was taken by surpise by downloading... they didn't really understand it. I thought, with something like this you have to be a little bit of a visionary, and you can't wait until it hits you. When it reaches the tipping point where it is going to be affordable, you have to be ahead of that game."

Cost is a key question, according not only to the authors but to other scientists and industry observers. Dave Geller, associate professor of machine technology at Oakton Community College in Skokie, Illinois, read the paper and commented that his department bought their 3D printer from another manufacturer, Stratus, for about $31,000, three years ago. That same printer now, he says, would go for $19,000.

"Price has come down a little over $10,000 in three years, but when we bought it, it was a relatively new technology, so we're on the steep part of the curve. It's going to flatten out a little bit from here. My guess is that, five years from now, you'll be able to buy something like this for around $10,000," Geller says.

He adds that the type and size of the printer also makes a difference. "Ours is limited to 20 x 20 x 30cm high. The newer one is 30 x 30 x 35cm. Well, it's a pretty good size depending on what you're making. If you're in the automotive market and you need the brackets for an alternator, that isn't big enough," Geller says.

Geller's department used their 3D printer to make 'bones' that were turned into casts to make plastic pieces for a model Tyrannosaurus Rex skull.

MATERIALISTIC VISION

Geller points out that cost is not the only variable in whether and when 3D printers ignite the public's imagination.

He says that one niggling point for him is that metal parts need to be 'printed' by first using a powder. Moreover, it's an extremely time-consuming process that can take hours and hours versus a quick trip to the hardware store, for example.

"Now, the Z Corp chain uses a powder," Geller says. "And ►

prospects for the future

3D PRINTING AND THE 'KILLER APP'

In their article, 'A Discussion of New Business Models for 3D Printing', Professors Cherie Ann Sherman and Philip Anderson claim that the modern 3D printer will be of use to a wide range of consumers – from the individual who loses his or her dental implant or eyeglass part to someone wishing to 3D print a child's toy.

The authors concede, however, that sometimes lofty schemes hit a bit of quicksand.

One unfortunate side effect might be what could be termed the 'Napsterisation' of STL files and the need for encryption or copy protection.

The forward-thinking and optimistic authors provide insights into how these snags might be handled, and into how 3D printing can evolve. "All this technology requires now is a 'killer app'," they conclude.

NICK SMITH

'There are probably at least four or five other technologies one could classify as similar enough to 3D printing to warrant a discussion'

when you are done, you have a very brittle object that looks a lot like ceramic, but is easy to break and crumble. It's nice if you want to make something to look at, but it's not too much good if you want to make something actually useful. You have to then dip it in some kind of hardener."

Geller says it's a difficult process, "and you get dust all over the place. Moreover, when making metal objects, one needs a sintering furnace".

"Anderson has some really good points," he adds. "Some of them are right on; some are way out and probably won't ever happen. If this thing is used to make models, it's great. And they do have some units out now that will print in powdered metal.

"But when you are done, you have to have a sintering furnace to put it in to heat it up to get everything to blend together," explains Geller. "Whereas Anderson says that if you need a spare metal part, you can just print it at home. Well, most people at home don't have a sintering furnace that goes up to about 2,000 degrees."

Anderson in his turn told *Engineering & Technology* that, in the early stages of 3D printing, plastic parts were fragile and required post treatment. Improvements in printers and processes have eliminated this problem.

Today, metal parts do require sintering, but it is very likely that 3D printers will continue to undergo significant technical improvements. In the future, sintering might be eliminated, or integrated into the 3D printer itself. This is a familiar pattern – traditional 2D printers have continued to improve from impact to dot-matrix to inkjet and laser technologies. Speed and resolution have increased dramatically, and the inks themselves have undergone continual improvements in set-time, durability and colour.

Whether that will transpire is still a long way off, according to observers. Jackie Fenn, a Boston-based technology analyst with the Gartner Group, told *Engineering & Technology* that, certainly as the 3D printer stands now, some ramifications may just not be possible.

"I think there are certain materials that it will work better with," she says, stating that, while a 3D printer is presently used for metal, it's being done so, for example, by artists who in turn bake their designs and have the equipment to do that.

"If one were to try using the 3D printer more ubiquitously, he might need alternative materials. You might use an extremely strong plastic, for example, as a replacement part. If it is a critical load-bearing element – something that must have a certain strength – you might not be able to achieve it, especially with the current generation of technology," she says.

STICKING POINTS

Sheku Kamara, operations manager with the Rapid Prototyping Center at the Milwaukee School of Engineering, says he believes that, in the paper, the authors are confusing rapid prototyping with 3D printing. The model they've designed is one entirely applicable to Z Corp but not to other printer manufacturers such as the aforementioned Stratus.

"3D printing is basically a specific type of printing created by Z Corp. The Dimension copier is made by Stratus and they use a hot glue gun. The deposits it makes are very thin plastic, applied layer by layer. That was the only point I disagreed with. My initial thoughts were it is only focused on the Z Corp process – 3D printing – but the potential of the Dimension and all the technologies, provided they meet the lower price point, is the thing Anderson and Sherman nailed correctly."

Kamara says the reason he believes a 3D printer is "specific almost to Z Corp" is because Z Corp developed the technology of using a print head to print with glue rather than ink. "This technology was developed at MIT and licensed through Z Corp, but they also licensed it to another company that also prints on metal," adds Kamara.

To this, Sherman responds that, indeed, rapid prototyping is a broader term than 3D printing. "But when we use the term 3D printing, we are referring to building plastic and metal parts directly from CAD drawings that have been cross-sectioned into thousands of layers." She points to an article, published in *PC Magazine*, that further states, "3D printing evolved from the 'rapid prototyping' industry".

Geller's school looked at Z Corp but considered Stratus the stronger choice. Both authors agree, however, that there are numerous manufacturers in the general market of 3D printing.

A QUESTION OF SEMANTICS?

Linda Schmidt, associate professor in the mechanical engineering department at University of Maryland, thinks it's a misnomer to use the term 3D printing in this particular paper – stating that a better title would have been '3D modelling', for example. "And, there are probably at least four or five other technologies I would classify as similar enough to 3D printing that I would think warrant a discussion in a paper like this," adds Schmidt.

"If they are using 3D printing as a term, they should be careful," warns graduate research assistant Greg Teitelbaum, who runs the university's Product Innovation and Realization Laboratory Suite (PIRLS) department and works with Schmidt.

Anderson maintains, however, that rapid prototyping is commonly referred to as today's state of the technology, and that he doesn't know if Z Corp has copyrighted the term '3D printing' or not, but 3D printing as we refer to it is a broader phrase referring to the future state of cheap, ubiquitous printers. ■

curriculum vitae

NEW JERSEY'S INVENTOR OF THE YEAR

Dr Philip Anderson's inventions have resulted in over 100 patents worldwide. Among them is the Acoustomagnetic electronic article surveillance system (EAS) and tags.

Anyone who has ever set off an alarm at a department store knows this invention: a white plastic security tag dangling from a garment – a component of an electronic surveillance system. It helps to prevent shoplifting, replacing earlier security systems that were prone to false alarms and inferior detection rates.

With this technology, which Anderson invented in 1987, the system sends out a magnetic signal that excites the tag into mechanical resonance, much like striking a xylophone key with a mallet. The system then looks for the distinctive response of the tag and sounds an alarm.

The invention significantly improved the detection rate and it also eliminated false alarms of previous technologies. In addition to the anti-theft function for retail stores, such systems are used in hospitals to protect newborns against abduction.

Another commercially successful invention of Professor Anderson's is the use of zero magnetostriction alloys in magnetic EAS systems. Magnetic EAS systems differ from Acoustomagnetic in that the tags generate harmonics of the system's interrogating signal. As these tags are very thin and flexible, these systems are typically used in libraries.

He has also invented devices to monitor children and prevent them from wandering out of a store while the parent is shopping and to protect surgery patients from having surgical implements, including sponges, inadvertently left inside them after surgery.