

Post-industrial manufacturing systems : the impact of emerging technologies on design, craft and engineering processes

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In a keynote speech at the recent Siggraph 04 conference in Los Angeles, the science fiction author Bruce Sterling explored the topic of 'When Bobjects rule the world' and spoke eloquently about the way technology was poised to take society as products themselves changed. He said that up to this point in history there had been four classes of objects: Artefacts - simple products produced by hand; Machines - complex mass produced objects; Products – bought and owned by consumers; and Gizmos – highly functional but short lived technological objects. He posited that as we have moved from one class of object to another, our relationship with objects has changed, that different material cultures have produced and been produced by different classes of objects. It is a truism to say that the mode of production and even the mode of retailing affect the relationship we have to objects.

He also speculated that new production technologies will mean a far higher level of consumer involvement in specifying the end product, and that that involvement means that consumers will become participants in the production cycle rather than mere consumers of products.

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Post Industrial Manufacturing Systems

The 'Future Factories' project is an example of the kind of post industrial manufacturing system which will bring about the kind of societal change predicted by Sterling. It is an exploration of the possibilities for flexibility in the manufacture of artefacts inherent in digitally driven production techniques. In essence the project proposes an inversion of the mass production paradigm to one of mass-customisation.

However, unlike previous work on mass-customisation, where many design decisions are taken by the consumer or with reference to the particular consumers needs, 'Future Factories' considers individualised production – in which a random element of variance is introduced by the computer within a parameter envelope defined by the designer. Each artefact physically produced will be a one-off variant of an organic design that has been defined by the designer and maintained in a constant state of metamorphosis by the computer software [[Figs 1 to 4](#)]. This variance may be over parameters such as the relative positioning of features, scale, proportion, surface texture, pattern, and the like. These variable factors may be multiple and interrelated. The intention is to achieve subtly different aesthetics based on a central theme rather than mere differentiation that might be achieved by, say, scale or colour change alone.

This random variance simulates the lack of uniformity in one-off craft production where the craftsperson may be guided by a design intent rather than a toleranced production drawing. In this way, 'Future Factories' aims to overcome the split between the technological and the aesthetic, between artistic creativity and machine production

We do not claim here that the notion of computer generation of random form is an original one in itself. The capability of computers to add an element of random selection to any mathematical function has been long appreciated. As computers have increased in power and speed, the capacity to randomly generate complex three-dimensional forms can be seen as a logical development of that capability. Perhaps some of the best-known computer generated forms are those resulting from the collaboration between the artist William Latham and the mathematician and computer graphics expert Stephen Todd. The system has developed a great deal since, most notably in its widely disseminated form as the 'organic art' software package [[Fig. 5](#)] (Computer Artworks 1995); yet its potential has not yet been fully realised. The 'Future Factories' concept explores this potential.

Using solid modelling computer software to create sculptural forms has also been taking place for a number of years. These forms, [[Figs. 6 and 7](#)] exhibited as part of the recent Siggraph 04 conference in Los Angeles, were designed by Keith Brown at Manchester Metropolitan University using 3D Studio Max, and then produced by rapid prototyping processes to create the actual sculpture.

Envisage a future where you could visit a dedicated 'Future Factories' website, accessed in a gallery, a department store or directly from your own home. [[Fig. 8](#)] This website would display a range of products, and you could select any one of them. Once you made a choice, you would be presented with an animation, which would show that particular product in a constant state of metamorphosis, as it grows, changes and mutates on the screen. At any given moment you could pause the animation and view a three-dimensional computer model of the product, rotating it to see it from any angle. The animation would continue, and any number of 'snapshots' of the product at various stages of its growth could be taken, and if required, printed onto paper for closer examination. Each one of these 'snapshots' would be a unique form – never to be repeated. If you then decided to purchase one of the designs, you could order it directly from the website, and the product you had selected would be manufactured automatically, exactly as you had seen it on screen, and delivered directly to your door. An original. A one-off. A work of art?

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The creation of computer generated art has little in the way of physical constraints. The adaptation of these forms into functional products though, obviously requires stricter control. Advances in computer added design have brought a shift to parametric solutions as a methodology for the definition of computer models (3d designs). In parametric design, relationships between the degrees of freedom of a model, instead of the degrees of freedom themselves, are specified. Using parametric design software designs can be quickly manipulated, and alternate solutions considered, simply by changing the variables, or parameters that define the product.

The 'Future Factories' designs are defined by 3d parametric models. In these models, ranges are set for certain parameters within which values are assigned at random by the computer. The limits of the range, along with further interdependent parametric relationships are imposed by the designer to maintain function and the desired aesthetic. This leaves an organic model free to mutate within a series of interrelated parameter envelopes. Each organic design is defined by a production formula, which can yield an infinite range of equally valid outcomes. We are able to categorise objects in nature by the recognition of certain common patterns and proportional relationships in spite of significant variance. 'Future Factories' aims to achieve this same balance between order and chaos, between manufactured uniformity and individual sensibilities. It aims to develop a system for the automated production of one-off outcomes that are at once distinctly individual and at the same time of a recognizable design.

Two fundamental approaches to the concept of product variance in the FF model have been identified in the work to date; manipulation of the core 3D form and the application to the core 3D form of a variable feature.

As an example of the first approach, a three-legged candlestick was designed, having a series of functional requirements – to stand upright and support three candlesticks of a fixed size [Figs. 9 & 10]. The candlestick's footprint is fixed, the legs being evenly spaced and at a fixed separation, for stability. The tops of the legs are also constrained but not fully. Each top is required to remain in the same radial plane as a foot, again for stability. The height of each leg may vary, separately, between a maximum and a minimum value. A relationship is applied to ensure an even spread of heights between the legs. This relationship prevents an outcome with two legs close to maximum height and one close to the minimum, or the reverse scenario. The only constraints on the form of the legs between top and bottom are the degree of interference required for a joint to be made, and that the legs spiral in the same sense and in a smooth curve.

As an example of the second approach, a light fitting was designed which took the existing form of a light bulb, but with a solid metal body [Figs. 11 & 12]. Instead, the light source is a series of high intensity white Light Emitting Diodes (LED's) mounted in the ends of 'tentacles' which appear to grow at random from the bulb form. The end of each 'tentacle' is dimensionally constrained to accept an LED and the direction in which the LED points is restricted to certain angles from the vertical (to avoid glare). Three distinct characters of 'tentacle' have been designed;

'Drops' form like stalactites on the lower half of the bulb tapering as they 'grow' downwards as if under gravity.

'Tentacles' form like drops from the lower half of the bulb, these however are able to resist gravity to an extent, they have a tendency to curl and coil.

'Risers' form like stalagmites rising from the upper half of the bulb. As they rise they lean out from the bulb body and begin to curl under gravity.

These 'Tentacle' types appear in varying proportion and random positions over the bulb form. Each can then vary in form based on its type.

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It is clear to see from the detailed description of the 'Future Factories' project that it represents a true convergence of art and science; the aesthetic and the technological; between creativity and production. This integration of the human perception of beauty; the randomly mutated, computer generation of form; and purely neutral cutting-edge industrial production is a far more complex issue than it might at first appear. This is no simple human/machine interface or human/computer binary opposite we are dealing with, but art and science as one.

The adoption of such a design/production paradigm as the one being put forward by 'Future Factories' raises a whole series of complex issues about the role of the designer. If the user makes an aesthetic judgment on a form, the precise configuration of which has been generated by a piece of software, then who has 'designed' it? Is the designer's role in setting up the algorithms to be employed, the variables and constraints within which the computer generates the form, and the parameter envelopes which limit the amount of variation a major contribution to the finished artefact, or a fairly arbitrary minor consideration?

Consider the following definitions of the two areas to see how the 'Future Factories' concept acts to blur those boundaries and distinctions. If 'craft' is taken to be concerned with the conception of form leading to one-off production; and 'design' is taken to be concerned with the conception of form leading to the production of a specification for later large-scale manufacture by a third party, then the distinction between a craft-person and a designer is clear. Following this distinction, 'Future Factories' aims to allow the use of a designed system to select a form randomly generated by computer software for immediate one-off production by machine. Although such a system has the capacity to make an infinite variety of related forms, it also has the capacity to reproduce exactly the same form, to a massively high level of accuracy, for an unspecified number of repetitions.

The 'Future Factories' system, then, would be seen to fit both the definition of craft, in that it allows one-off variations in form; of design, in allowing repetitive production of the same form; or neither as the form is not generated or conceived by the person who selects it, or even by the designer who specified the parameters within which it was designed. In this context, the previously understood definitions of 'craft' and 'design' as discrete processes become hopelessly blurred, intertwined, inextricable, and as a result, meaningless.

The project explores the role of chance, of unforeseen elements in the production of the 'finished' work. In a research context, the accidental, the random and even the unaware as contributory constituents are considered as aspects which have considerable impact on the definitions, roles and expectations of the author, the mediating technology and the consumer within the creative process. Aspects of 'control' over the results of creative endeavour which are normally taken as a given are here questioned and ownership of the process debated. As high level pieces of original practice-based research such uncertainty is understandably problematic.

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The project utilises real-time networked technologies in its final manifestation and contextualises the shifting relationships between the maker, software techniques and the participation of the audience or consumer in a playful and game-like process in the production of the finished artefact.

To add to the allure of one-off products, there are a number of ways in which the 'value' of the artefacts produced might be increased. An element of exclusivity can be introduced for customers such as corporate buyers, for whom specific commissions could be undertaken and unique design formulas produced. They could then order as many of the objects (such as light fittings for a particular chain of restaurants) as they required, secure in the knowledge that each product would be unique in itself as well as the design formula being unique to them.

Alternatively, the production of designs can automatically be 'capped' to a specified quantity as is the case, for example, with limited edition screen prints, with a numbered system being used to show how many have been produced, and how many opportunities to own a one-off variant of a particular design are left. Another option is not to cap the quantity, but to limit the amount of time for which any particular product will be produced.

Perhaps the most interesting possibility for increasing value is to employ the model of a single line of 'evolutionary' development in which a design is created, adapted and finished over a specified time span. Imagine a simple design being created for production for a period of, say, six months. Over that period, the design might become more and more complex, more organic, or more convoluted in form until it reached the end of its 'growth' pattern when it would no longer be able to be turned into a real object. At any point during that period, customers could view how the object started out and how it has developed since its inception. They could have the option of purchasing the object at that point (but not be able to purchase any of the forms from a previous time), or anticipate, like gamblers playing a game of chance, how the design might look in a month, when they might return and purchase it. They might plan to purchase a range of objects from a number of different points in its existence, or vectors along the animated production line. It is possible that 'early' incarnations of the design could become more valuable than later ones (as with limited edition screenprints having lower imprint numbers). The possible combinations of ways in which the process could be employed are potentially huge and are currently forming the basis of a funded attempt to commercialise the technology developed.

The 'Future Factories' project demonstrates that the potential of computer-generated organic forms to produce viable artefacts for one-off production is at last a realistic proposition. Obviously, 'Future Factories' is not a suitable model for the production of complex technological objects (at least not yet). But the design thinking behind it, and the manufacturing system proposed fits comfortably with today's drive for individuality.

In 'Future Factories' a direct connection is made between playful desires and the will to take risks through predictive forecasting, as well as connecting with dominant modes of capitalist production via the technologies if not the processes of mass production. 'Future Factories' is not mass customisation, the mode of production is craft placed momentarily in the hands of the consumer, temporarily liberating them by engaging them in a culture of chance, variability, selection and playfulness. This enables the consumer to engage with a plethora of possibilities through chance decisions that ultimately capture a particular moment, through which a unique object is cast out from a virtual environment into the real world.

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Conclusions

It is clear that 'Future Factories' is an example of emerging and converging technologies and new practices which are combining to form a new position for the maker and author as the source of the final artwork. The designer may not, in fact, even be aware of products selected and produced in his name. In this case, the combination of mathematical algorithms and autonomous production processes potentially isolate the author from the outcome, and leaves hanging questions of responsibility and ownership.

Finally, the use of software processes and real-time networks as generative tools forces not only the questioning of transient boundaries, but also the relevance or irrelevance of conventional definitions and the accepted nature of the roles, practices, techniques and processes involved. It is clear that the outcomes of these new models of creative production cannot be thought of as traditionally conceived pieces. They are, without doubt, art. Outside of that, definitions convey little of the reality of their production. The outcomes shift boundaries as they lie in some new, as yet unspecified arena of production.

The challenge for craft as a discipline is how does it retain its identity, when technology conspires to remove the distinctions between hand crafted products and machine made artefacts?

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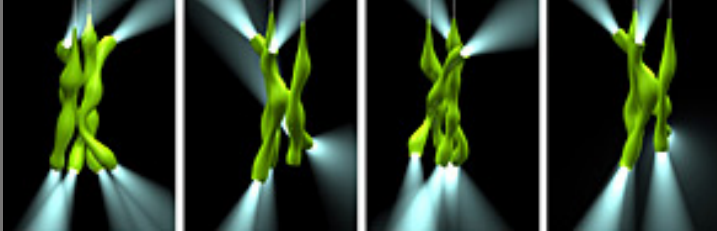


Fig 1 to 4

Four frozen moments of the
'Tuber' luminaire morphing



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Fig 5
A screen grab of the
'Organic Art' Software
from Computer
Artworks



Fig 6 and 7
Sculptures by
Keith Brown of Manchester
Metropolitan University,
realised by rapid prototyping.
Images courtesy of Keith Brown

Future Factories

- A web-based system for selecting and producing unique artefacts produced by direct digital manufacture

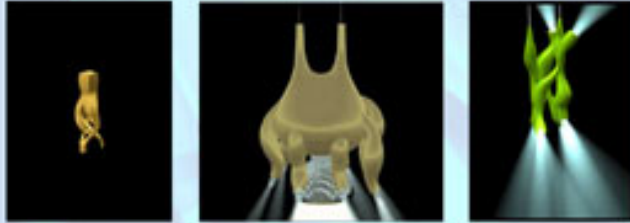


Fig 8
Website concept



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Fig 9 and 10
The 'Let's Twist Again' candlestick



Fig 11 and 12
The 'Lampadina Mutanta' Luminaire

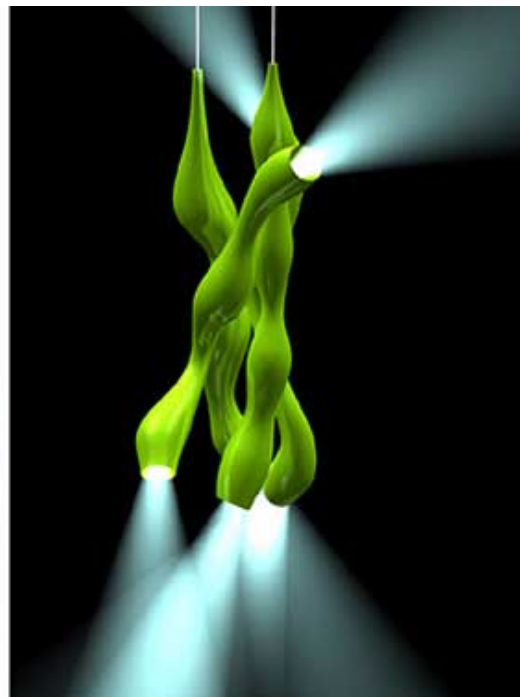
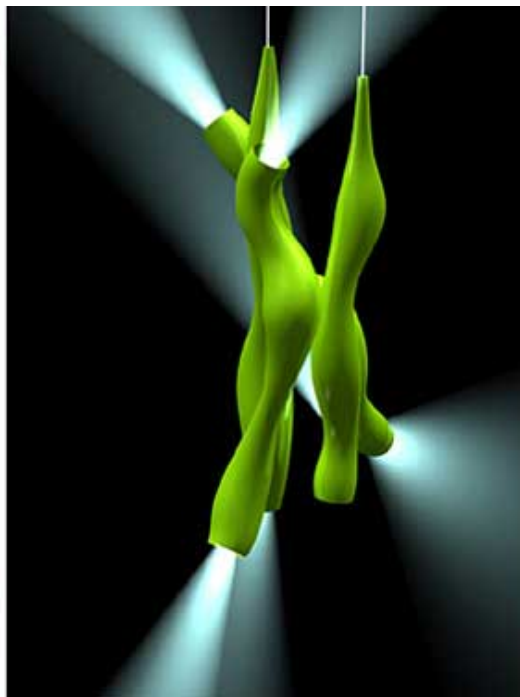
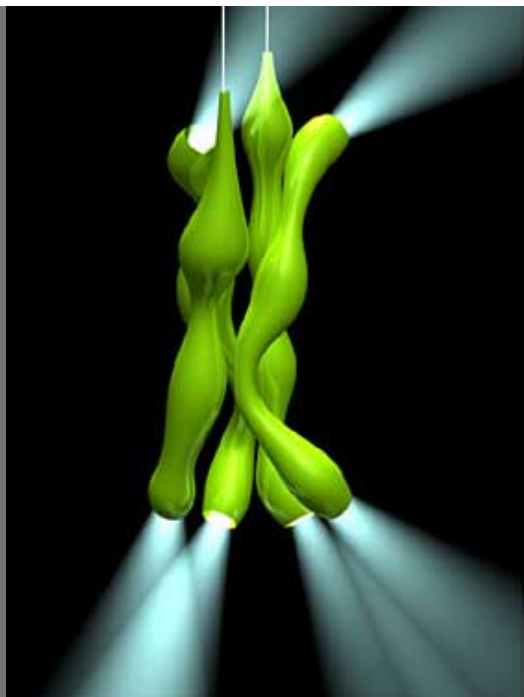


Fig 5

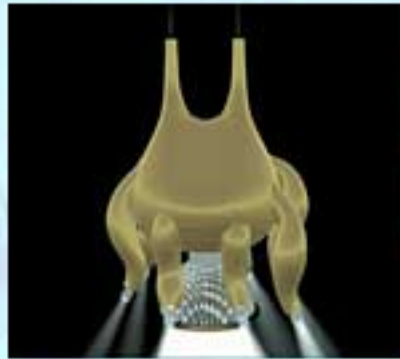


Fig 6-7



Future Factories

- A web-based system for selecting and producing unique artefacts produced by direct digital manufacture



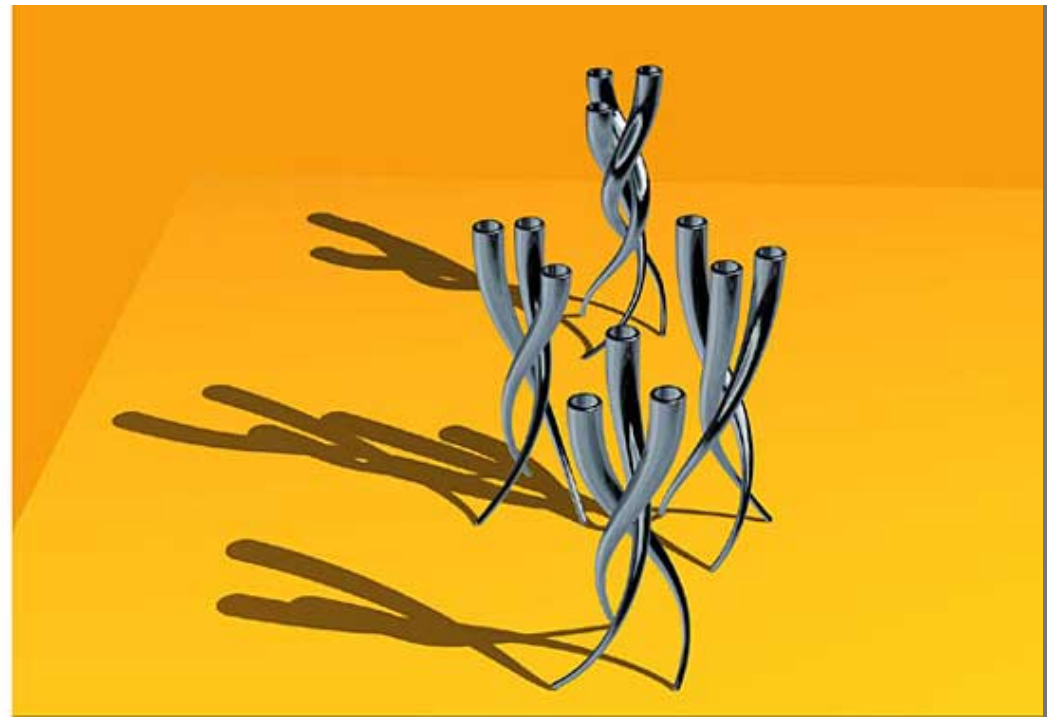


Fig 11-12

