FutureFactories : Inverting the Mass-Production Paradigm

Abstract
FutureFactories is an exploration of flexible design and manufacturing made possible by digitally technologies: principally, but not exclusively, rapid prototyping (RP). The aim is individualised production, the industrial scale manufacture of 'one-offs' via an element of computer generated random form. Designs exist in a state of constant metamorphosis morphing within an envelope set by the designer. FutureFactories aims to overcome the split between artistic creativity and machine production; blurring the boundaries between traditional interpretations of 'Craft' and 'Design' (and even Art). The project began as a design residency at the University of Huddersfield in the summer of 2002, it has now been expanded into a practice-based PhD study.

Computer generated artwork has become commonplace. The creation of three dimensional artifacts from this artwork however imposes considerable limitations and is consequently rare. Advances in digital technologies have made the creation of 'one-off' products from computer generated models, a realistic, affordable, possibility.

FutureFactories is very much a practice based study. The target of the residency program was an exhibition featuring a collection of 3D designs. Five design 'templates' were created for the exhibition which toured regionally from Autumn 2003 to Spring 2004, before going on to Milan and London. There was constant tension between desired aesthetics and what could be achieved with an embryonic design system. Budgetary considerations resulted in pushing the boundaries of the cheaper 3D printing processes. As the project has gained momentum, support from the RP Industry has allowed the use of more exotic RP methodologies and materials. Models that had hitherto required considerable post-finishing were now ready straight from the machine, proving FutureFactories a viable production concept. Evolution versions of the first collection were exhibited in London Design week, September 2004, and at the time of writing they are on display in New York.

Introduction

FutureFactories has no fixed designs. Instead of creating a single discreet design solution (or indeed a finite range of options), the designer creates a template. This template defines not only the functional requirements of the form but also embodies the character of the design. Through the design template, the designer establishes a series of rules and relationships which maintain a desired aesthetic over a potentially infinite range of outcomes. The design becomes a 'living' entity, continuously morphing within its template envelope (Atkinson and Dean, 2003).

Technological context

Three principle digital technologies exploited in the FutureFactories production model (fig. 1).

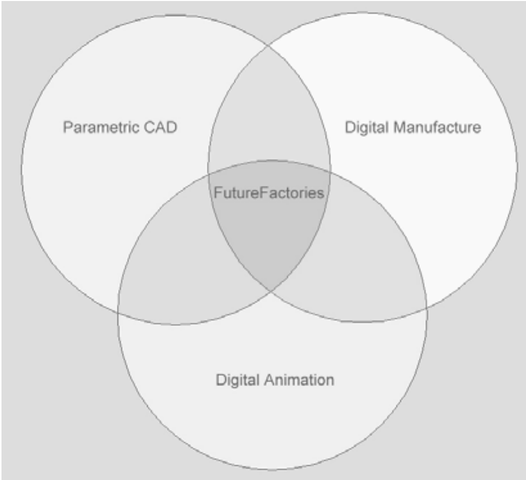

Figure 1
The three core digital technologies exploited by FutureFactories

Parametric computer aided design

Parametric computer aided design (CAD) enables the designer to define relationships that form the character of a design rather than an absolute solution. Parametric design considers the relationships between degrees of freedom rather than the degrees of freedom themselves. If individual variables in the 3D model are modified, the whole form will up-date to maintain specified relationships.

Digital Manufacture (Rapid Manufacture, Direct Manufacture)

Rapid Prototyping (RP) is a catch-all term that applies to the digital manufacture of prototypes directly from CAD data. Essentially RP allows on-screen models to be 'printed out' in 3D. Most of the recently developed processes are layer additive. Software 'slices' the CAD model into thin layers (down to 0.05mm). The model then 'grows' one thin layer at a time as each data 'slice' is replicated in 3D from the bottom up. The layers are built on a moving platform, each built on its predecessor as the platform steps down in layer thicknesses. There is no tooling or cutting away of material: this allows unlimited geometry. Forms may be produced that would be almost impossible to mould or machine.

Now that Rapid Prototyping (RP) is well established – the new frontier for the digital manufacturing industry is Direct Manufacture. Direct or Rapid Manufacture is essentially the adaptation of RP technologies to the manufacture of end-use products. "A number of compelling examples of RM suggest that it will span across many industries in the future. Among these are hearing instruments, dentistry, medicine, aerospace, military, oil exploration, motor-sports, and consumer products" (The Wohlers Report 2003). The relatively slow layer-by-layer building, inherent in the processes means that digital manufacturing is unlikely to ever match production capacity of say, die casting, or injection moulding. Manufacturing parts, without the need for moulds or dies, does however makes the volume production of individualised forms an economic possibility.

Computer graphics and digital animation

FutureFactories product forms are not fixed, the designs exist in a state of constant flux. To appreciate this, customers should be able to see the designs continuously 'morphing' in real time. The concept lends itself to some form of 'virtual' web-based merchandising (Unver, Dean and Atkinson, 2003). A marketing experience is envisaged in which the consumer is presented with a 3D animated model via a website. The consumer may access the website directly or via a sales outlet within, for example, a gallery or a department store. Advances in the graphics capabilities of home PC's and the speed of internet connections allow the display of rendered forms mutating in real time on the customer's home computer. Memory hungry 3D rendering now exploits graphics processors on the video cards instead of consuming valuable CPU resources when drawing 3D images. These advances in video cards and the software that manage them, driven hard by the video game industry, enable the smooth real time display of animated forms complete with realistic scene lighting and material finishes.

The concept

The product forms of the FutureFactories artifacts are defined by surface-based 3D models. The surfaces themselves defined by control curves. It is these control curves that are manipulated during the mutation. Each 3D iteration is defined by a list of parameter values. Parametric CAD generates the 3D from this list (fig2).

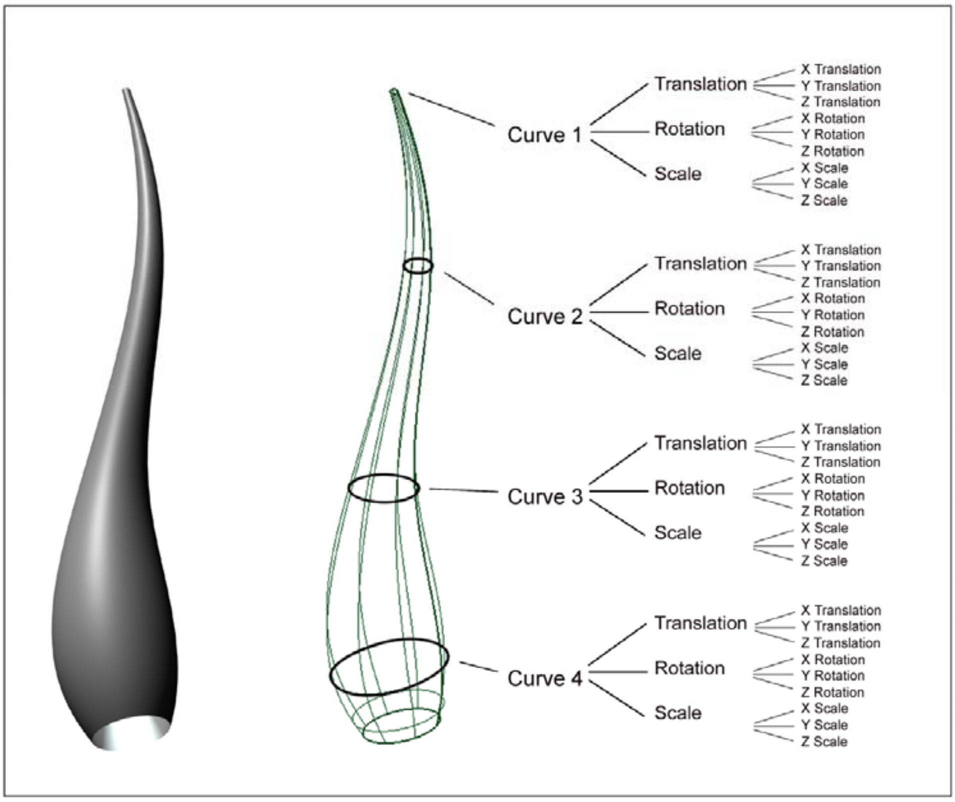

Figure 2
The CAD model and its associated list of parameters

When mutation is initiated certain parameters are re-assigned random values from within specified permissible ranges: this creates a revised model. Proportional relationships between characteristics maintain the character and aesthetic of the design, whilst range limits ensure functionality. Rather than jump directly to the new form, animation is employed to move gradually to the new position over time. This allows smooth, flowing transitions rather than staccato jumps when the model is viewed in metamorphosis. When the model reaches its new position the random values are re-assigned and the process repeats itself. At any given point the animation can be halted and the model exported as an .STL (Standard Triangulation Language) file for digital manufacture.

The manufacturing processes used

The first FutureFactories product collection featured domestic lighting and tableware designs created using a variety of software packages. 3D printing processes (3DP) were used for the initial production because of their relatively low cost (multiple iterations of each design would be required).

Early versions of the Tuber pendant luminaire (fig. 3) were built using a powder based 3D printing process. In this process layers are built by applying a binder to a plaster-based powder. The resulting porous model is then impregnated with either cyanoacrylate (superglue) or wax in a post-production process. Absolute dimensional accuracy was not important at that stage, only the character of the form. Surface finish was not an issue as a high quality paint finish was specified; there would be hand finishing whatever the process used. Removing the loose powder from the somewhat inaccessible internal passageways (these serve as wire runs) proved a challenge, as did handling the delicate model prior to impregnation.

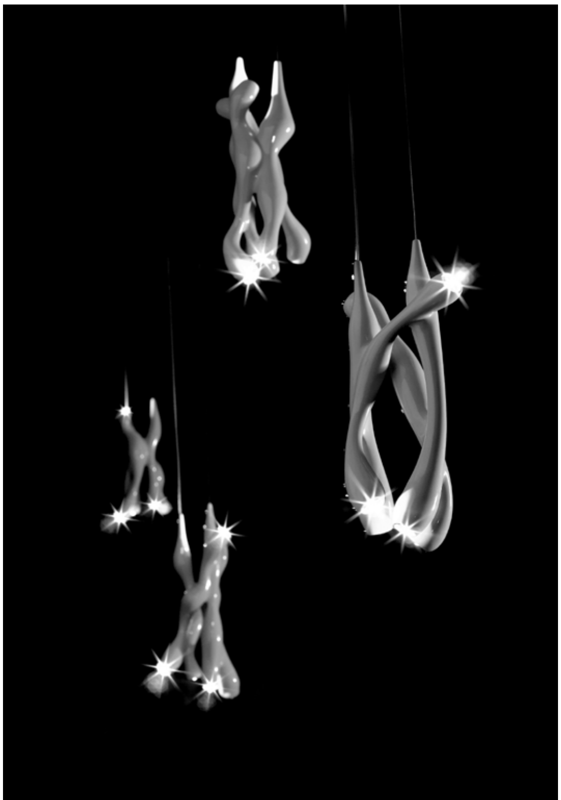

Figure 3
Iterations of the Tuber pendant luminaire

The later Tuber9 (fig. 4) was manufactured in laser sintered nylon, the prototype kindly provided by EOS, Electro Optical Systems. The use of laser sintering nylon brought translucency and high quality surface finish eliminating the need for post-finishing. The fine resolution of the system and the material properties of the nylon allowed the incorporation of snap-fits and a much more complex structure.

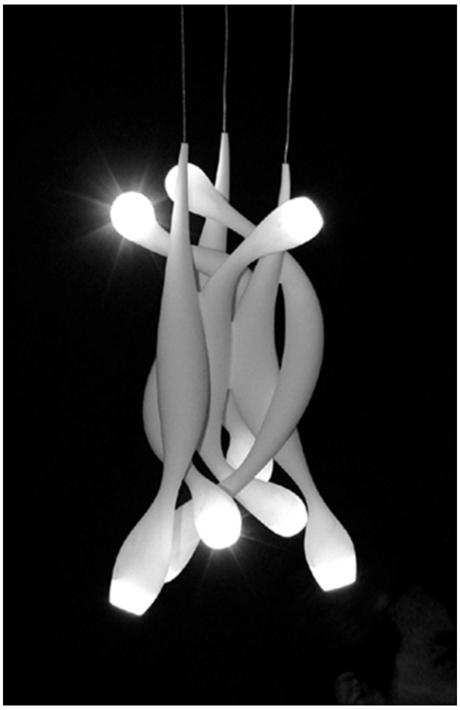

Figure 4
Tuber9 in laser sintered nylon
prototype courtesy of EOS, Electro Optical Systems

The Lampadina Mutanta (fig. 5) and Nautilus pendant luminaires were both designed for direct manufacture in SLS stainless steel. Budgets however, dictated a shift to investment casting from 3DP generated wax patterns. The main implication of this was an increase in wall thickness required for casting. Lampadina Mutanta has the size and form of a standard GLS lightbulb. An irregular growth of tentacles sprouts from the top and bottom of the bulb each bearing a white LED. These tentacles move around the bulb swelling and writhing as the design mutates. If too many LED's point in the same direction the solution is rejected and the random variables re-generated. The form makes full use of the flexibility inherent in RP processes. The closely grouped, hollow, curled tentacles are full of re-entrant forms (undercuts) that would be almost impossible to manufacture conventionally. The 3DP process for the waxes required the removal of support structures prior to investment casting. Castings have been successfully produced in stainless steel brass and bronze.

figure 5
Iterations of Lampadina Mutanta investment cast in stainless steel

The Twist three branch candlestick is also investment cast but in the instance from a power-based RP pattern. This pattern was produced using the same 3DP process as Tuber but with a starch-based powder designed for investment casting. The powder based process offered the advantage of no support structures but not all foundries are prepared to work with an unfamiliar material.

FutureFactories vs. Evolutionary Art
We do not claim that the notion of computer generated random form is in itself an original one. 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. Although the resulting ‘sculptures’ were only ever intended to be seen as 2D representations of complex 3D models presented as art in a gallery context, the principle behind it can just as easily be used to create variations on ‘usable’ forms to produce designs for ‘anything from buildings to shampoo bottles’ (Computer Artworks 2003).

Evolutionary art exists in a virtual world. The constraints of the physical world, gravity for instance, need not exist. Anything is possible and the images are usually scaled as required to fit a convenient screen area. “The scale of forms generated from the same structure can vary by huge amounts as the parameters change: a single family can easily include both whales and insects" (Todd and Latham, 1999). Functional products must adhere to physical rules. Organic art often starts with simple geometric primitives; effectively a blank canvas. FutureFactories starts with well developed, non random, seeded solutions. Coherent designs whose viability must be maintained throughout mutation. Rapid prototyping machines have build envelopes, into which parts must fit (although it is possible to subdivide a form into smaller components that are subsequently assembled into a larger structures using built in fastenings). Iterations of the same design, in spite of differences in form, should be produced in the same machine and use the same packaging (elements of protective packaging can be incorporated into the build process). Dimensions in FutureFactories are absolute, with limits imposed to ensure manufacturability.

The 'organic' nature of the FutureFactories designs

From the project's inception, communication of the FutureFactories concept was an important factor. The example designs created had a strong flavour of organic growth in the aesthetic. The name Tuber, the vivid green colour and the curvaceous form were all seen as factors in communicating the idea of growth. A frequent question raised is, given that the designs, to-date, have such a strong organic flavour – could the system be applied to other aesthetics, to something more geometric?

Beyond the 'marketing' of the concept, there are other reasons for the preference of organic forms. Firstly, the example products produced to date are the work of one designer: inevitably the work reflects his tastes and ideas. Secondly, the virtual models are literally growing: natural organic forms are the result of growth and so the connection is hardly surprising. Thirdly, one of the transformation types employed is a twisting motion. Twisting a form is almost certain to result in the generation of curves. Where surfaces are formed between control curves, they are geometrically constrained to flow smoothly one curve to the next.

Geometric aesthetics are not being overlooked however. One of the areas for future work is an evolution that favours the creation of flat surfaces, straight edges, and angular relationships between faces. The evolution would start from a simple organic base and evolve into something geometric and faceted.

Conclusions

The scope of the mutation possible within FutureFactories is restricted. It is limited by the use of standard components, by the geometry of the model, and by the requirement that the iterations remain recognisable designs, true to the designer's intent. Trials have shown us that customer demand is for significant change in the forms. It is also seen as desirable that, whilst conforming to a design idea, the mutation deliver some unexpected twists. The system does not allow for the evolution of new features from functionally compromised beginnings. Complex natural systems, such as the human eye, have evolved from something much cruder, like perhaps the light sensitive spots processed by some single celled animals (Dawkins 1986). One can imagine the parallel in the Tuber lamp. A new limb might evolve beginning as a small protuberance on the surface. This would elongate and develop a slight glow at the tip. The glow then intensifies, until it becomes the intense focused beam of the LED. This unfortunately belongs to the virtual world. FutureFactories is able to individualise product forms, but standard, interchangeable functional components are still required. An LED has a fixed size and specification. It is either there, or it is not.

The potential for evolution is restricted by the internal components in the sense that, whist the skin of the design might be allowed to mutate, significant areas of the form will be dictated by standard functional components. Ideally the entire product should be allowed to evolve including any functional components. It is possible that such components could be built digitally along with the body. This already happens with some simple mechanical devices for example, springs, bearings, clips and hinges. There are also machines capable of building in more than one material simultaneously. New materials and possibilities for digital manufacturing are emerging all the time, with ever increasing performance. It will become possible to achieve more and more functionality from digital builds.

The potential impact of FutureFactories has been noted and described since the first stage of this work as mentioned (Atkinson and Dean 2003) and are still considered to be significant. As the project has developed, additional elements have been recognised with respect to the system's impact on issues of authorship and accepted notions or definitions of design practice (Atkinson & Hales 2004).

Clearly FutureFactories is an example of emerging and converging technologies and new practices which are forming a new position for the maker and author as the creative source of finished pieces. In fact, the designer may not even be aware of products selected and produced in his or her name. The combination of mathematical algorithmic processes and autonomous production potentially act to isolate the author of the work from the outcome, and raises questions of responsibility and ownership.

Finally, the use of software processes and real-time networks as generative tools questions existing, transient boundaries of practice, and also exposes the relevance or irrelevance of conventional definitions and accepted nature of the roles, practices, techniques and processes involved. It is clear that the outcomes of such a new model of creative production cannot be thought of as traditionally conceived pieces. They are, without question, art. Outside of that, existing definitions convey little of the reality of their production: as they lie in some new, as yet unspecified, arena of production.

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