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Designing for RM: "Entropia" A Case Study

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Biography

Lionel is a graduate engineer and has a Master's Degree from the Royal College of Art, London. He designed for Pininfarina in Italy, before launching his own consultancy. Lionel's research activity focuses on computational design and mass-individualisation: the industrial scale production of one-off artifacts. FutureFactories, set up by Lionel in 2002, explores product individualisation via the use of Rapid Prototyping technologies and is the subject of a practice based PhD study. Lionel's professional practice focuses exclusively on Rapid Manufacturing. He has several rapid manufactured pieces on retail sale. In 2005 one of these, Tuber9, was acquired by MoMA, The Museum of Modern Art in New York for its permanent design collection.

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Abstract

FutureFactories is a design project that has the ultimate aim of mass-individualisation: the industrial scale production of one-off artefacts. This is to be achieved by the combination of genetic algorithms, parametric CAD and Rapid Manufacturing (RM). Mass individualisation itself remains a 'blue-skies' goal for the project (although it need not be that far away). RM, however, is already with us, and products developed by FutureFactories are currently on retail sale around the world. In April 2006, there was a significant development: Italian lighting and furniture manufacturer Kundalini launched, what it is billing as, the first Rapid Manufactured retail product by a recognised manufacturer (in other words not by an RP bureau). Prophecies such as this are dangerous, given that this is a fast developing field: it is certain however, that Kundalini will be amongst the first.

The significance is that Kundalini's primary function is retail manufacturing. RM could be considered as a logical step for the larger service bureau, unused machine capacity can be turned to production and the artefacts produced serve as marketing tools promoting the capacity, technology and expertise of the company. The products effectively become larger scale versions of the samples produced by machine vendors, only in this instance saleable. For RM to become 'mainstream' it must be adopted by those who have no vested interest in promoting the production process itself. The author has long argued that FutureFactories is not about the technologies themselves, but about their application and the creative opportunities that they facilitate.

From the outset of the Kundalini project, the client was dispassionate about process and entirely focused on form. The brief specified a product that would baffle, whose conventional production would be inconceivable. This departure from the predictable would apply not only in terms of physical manufacture, but in the very nature of the geometry produced. There should be no pattern or order, no hint of logic that would suggest how the form had been created. For Kundalini this could be the only justification for the relative expense of RM.

This paper will discuss, through the Kundalini case study, the implications of RM from a design perspective. It will look at the shift in new product investment from physical tooling to the design of increasing complex objects. From a RM point of view, geometry may 'come free', but this in turn will set up new market demands and expectations. The designer will need new skills, tools and understanding of the capabilities of Rapid Prototyping, in order to realise the potential of RM in the consumer products market.

Introduction

Entropia was launched at ‘Light and Building’, Frankfurt, April 2006, by Italian lighting and furniture manufacturer Kundalini (see figure 1). Kundalini celebrated its tenth year in 2006 and has a reputation for blending tradition and technology, mixing hand blown glass with 5-axis waterjet cutting for example.

Entropia’s principle component is a 120mm diameter spherical diffuser, produced in laser sintered nylon. The design is available in table, suspension, and wall variants. It retails between 400 and 500 Euro depending on the model: a price comparable with traditionally manufactured artefacts from design-led manufacturers in materials such as hand blown glass and ceramic. Kundalini had no previous experience of Rapid Manufacturing (RM) or even Rapid Prototyping (RP). The company was, however, familiar with the work of FutureFactories. The company had previously expressed interest in FutureFactories’ aesthetics, but until recently had considered that the time was not yet right for the technology to be used in a retail context. The plethora of RP based concept work seen around the world and the promotion of RM by the RP industry began to modify that view point. In Autumn 2005, it was decided that the idea needed serious consideration and the author was commissioned to create a series of concepts. Simultainiously talks began with RP service bureaux and equipment vendors to explore the economic viability.

Figure 1: Entopia table, suspension and wall variants.

From the outset Kundalini was extremely passionate about the aesthetics that might be achieved but never at the expense of commercial viability. This was to be a retail product; the price of which would be determined by the market. It was evident from early exploration that the best chance of viability lay in a compact form and that the more efficiently the build chamber was filled, the more cost effective the process would become. The cost of a build would be split between the number of components contained within it. Squeezing in one or two extra units would have a significant impact on price and may prove to be the difference between viability or not. Early in the concept design stage a spherical form emerged as the most likely solution as the design needed to be as compact as possible and leave a certain clearance around the light source for reasons of temperature. A diameter of 120mm was arrived at as offering the best balance of perceived value and manufacturing cost. Despite this compact nature the design would use G9 halogen fittings, these run at line voltage, eliminating the cost of a transformer.

Form

It was important to Kundalini that the design was taken as far away from conventional industrial manufacture as possible. Complexity was a given: any regular form could be produced more economically by conventional means. The idea was, however, to go beyond awkward geometry. Although certain forms may be impossible to produce conventionally, such as undercuts, re-entrant shapes and the like, this fact will not necessarily be appreciated by the lay customer. To the consumer it makes little difference if a product is produced in one piece via some exotic means or is made as a well disguised assembly of cheaper components. The freedom of RM brings the risk of engaging in party tricks that are only appreciated within the industry itself. The author recently showed a lay audience a sample of SLS manufactured chain link. The audience was unimpressed, plastic chain link could be bought from the local DIY superstore. The aim of this project was to create a form that would intrigue, baffle and captivate everyone. It would be necessary to convince the buying public that a particular piece of plastic was every bit as valuable, if not more so, than for example, a piece of hand blown Murano glass that would sit beside it in the Kundalini collection. The idea was to remove all traces of pattern and logic from the form, to eliminate any accessibility or key to understanding. The principal of this was easy to grasp: achieving it in practice, less so. The language of traditional ‘design-for-manufacture’ had to be abandoned. There could be no repeats or symmetry. At the same time it needed to be evident that there was process behind the form: a totally random assembly would not be considered particularly valuable.

The solution was to adopt the rule based approach used in previous FutureFactories morphing designs. In these designs virtual models were created that allow a design to morph within a parameter envelope set by the designer. Rather than yield a discrete 3D solution these designs were templates from which multiple one-off solutions could be generated, each functional and true to the designers' intent (see figure 2).

Figure 2: FutureFactories Tuber iterations.

In the case of Entropia, design templates were created for a series of features that would appear in varying numbers throughout the form. These templates dictate the underlying style of a specific feature but allow considerable flexibility in it's particular embodiment (see figure 3).

Figure 3: Iterations of an Entopia rule-based feature.

Each time the feature is repeated within the form there is a slightly different outcome. The result is the impression of a natural phenomenon, such as coral. There are clear patterns to the ‘growth’ but the form appears to have evolved rather than to have been constructed (see figure 4).

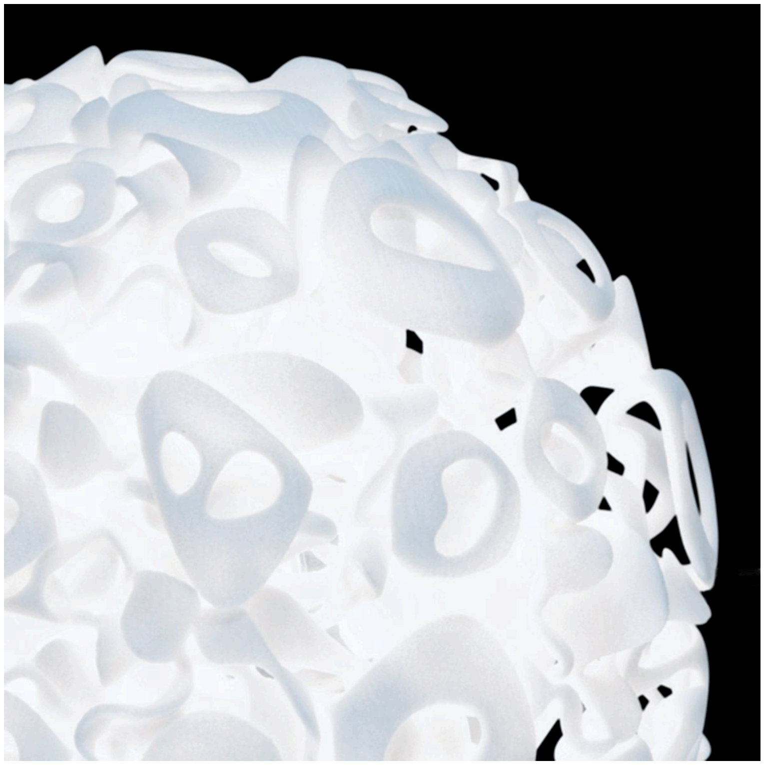

Figure 4: Entropia, detail.

Rapidity

Product development speed was not a primary consideration in this project. Speed is more applicable to the prototyping side of RM rather than series production. The emphasis placed on rapidity by service bureaux, which is such an asset to prototyping, is often a hurdle to RM. The bureau industry is often characterised by feast/famine workloads and large amounts of overtime. This does not lend itself to RM, where efficiency is key and profits are made over a longer term.

Whilst not a primary consideration, RM enabled an extremely short product development cycle. The concept was agreed in early January 2006 and the product launched in April 2006. Despite the design’s compact nature, the level of complexity in the form required a great deal of 3D modelling. RM allowed prototypes to be built based on sections of the design that were complete: incomplete sections were either replaced with simple approximations or simply omitted. This enabled technical developments to take place in parallel with the design of the form itself and allowed the compressed timescale.

Conclusions

Complexity
Aesthetics are subjective and the merits of this particular design are not an issue for this paper. A significant factor, however, is the demand for complexity: a demand coming from the client but driven by the consumer. This demand is sure to increase as the almost free-form potential of RM becomes more widely appreciated. Greater use of computation in the design process is called for to manage this complexity.

Visualisation
Visualisation is a major issue. It is difficult to orientate oneself in a complex on-screen model. Locating a specific area in a form as complex as Entropia is far from easy. It becomes hard to identify issues that would be readily apparent when handling an actual prototype. A far greater range of more flexible visualisation tools built into CAD software systems would help here.

Visualisation is also an issue for the consumer where there is no sample product to assess. FutureFactories is frequently asked where designs, published on the website, can be seen in the flesh. If only a few artefacts are made to satisfy a market niche, it would not be economically viable for stock to be held at retail outlets worldwide, manufacturing to order would be more appropriate. Visualisation beyond the brochure studio photograph is required to convince all but the most avante-guard of buyers, better interfaces are needed to enable consumers to assess products remotely and order them with confidence. Some form of web-based virtual reality, computer-based experience that mimics real experience, may provide a solution. It is perhaps the high-end VR systems that come first to mind with the user wearing special goggles and gloves. At its simplest however, VR could be a 3D view of the product that the user can rotate to see from various angles. In this way potential customers would be able to examine the 3D model moving, rotating and zooming in and out, at will. Such ‘hands-on’ interaction would allow something of a “try before you buy” experience.

Investment
It is worth noting that although RM eliminates the need for tooling investment, current marketing practices require investment in printed catalogues and the like. As a designer, it is tempting to believe that manufacturing will become far more flexible and versatile, able to experiment and react quickly to niche markets. In practice it is an attitude that will take time to develop within the industry and consumers will also need to adapt.

The lack of tooling investment removes a key point from the design process; the point at which production drawings would be passed to a toolmaker. With RM design development can continue up to the eve of a product launch, but need it stop there? A situation can be envisaged similar to software releases with a product improving by degrees during a production run, versions 1.0, 1.1, 1.2 etc.

Process

The traditional product design development model begins with loose concept sketches that gradually become more and more refined as the project develops. Practicalities are fed in gradually, so as not to kill the style of a concept. When computational design is employed the initial priority is in setting up relationships, parameters and formulae; rather than looking ahead to what they will ultimately produce. Complexity by its very nature cannot be easily reduced or predicted. With Entropia, the importance was in defining a language for the elements used. The initial design issue was the definition of developmental rules that would allow diversity yet keep the form true to the designer's intent. Creating such rule-based systems takes time and requires something of a 'leap of faith' on the part of those commissioning the process. It is not possible to generate outcomes before the system is established. Once the rules are in place however, any number of design iterations can be generated with relative ease. It is easy to imagine a step on from the current Entropia, in which only the size and developmental rules are pre-defined. A unique form would be 'designed' every time a 3D iteration was generated: this would be the FutureFactories concept of mass-individualisation. The issues that hold back such an idea are the demands of setting up the model and customer acceptance. A virtual model capable of generating endless one-off outcomes must be created: a process that must be automated as, in industrial scale manufacture, a designer cannot modify each and every item produced. Consumers would need to be aware of the concept and celebrate the difference. Manufacturers considering individualisation fear endless product returns as the product received does not match up to another.

Optimisation

Currently, the placement and arrangement of models within the build volume is undertaken by RP bureau staff: they are presented with the model when it is complete or in the final stages of development. The efficient use of the build volume is the most important factor in determining the viability or otherwise of Rapid Manufacturing projects. It is vital that the concept is tailored from the concept stage to use the chamber efficiently and to allow the accommodation of a commercially viable number of units. Ideally, software for this function, would be brought within high end CAD packages so that it can be referred to by designers throughout the design process rather than existing as a stand-alone package aimed at machine operators.

Material

In RM for the decorative design market, public perceptions of material value becomes an issue. Plastics, however exotic, do not have the same cache as, for example, glass or ceramic. Hand blown glass artefacts sit beside Entropia in the Kundalini collection and are comparable in price. This perception of inferiority can be combated to some extent via design. Fine detailing and delicacy of proportion communicate quality and craftsmanship. This becomes exaggerated in lighting applications where translucency accentuates fine section thicknesses (see figure 5).

Figure 5: Texture of SLS nylon when lit (FutureFactories, Tuber9).

In the laser sintered designs of FutureFactories, thicknesses can be as low as 0.5 mm. This is well below that which would be recommended for the process. Many bureaus give a standard warning if model section thicknesses drop below 2 mm, Entropia does not have any sections above 2 mm. In fairness, robust sections are encouraged because of the cost of the process and the risk of scrapping parts. FutureFactories plays with thickness ensuring that there will always be an appropriate structure. Ultra-fine sections are used in areas that are purely decorative and forms are preferred that will not suffer unduly should fine edges not build completely. Whilst it has not been used as a policy in the output of FutureFactories, redundancy could be considered to mitigate the risk of failure in minor decorative elements. Where there are massed numbers of features following no discernible pattern, the absence of one or two may pass unnoticed should they fail (see figure 6).

Figure 6
Massed minor elements seen in FutureFactories Creepers, 2005

Early FutureFactories work featured hand finished (paint finish) artefacts built using budget 3D printing processes. It soon became clear, however, that the budget RP processes were still expensive in relative terms and that hand finishing on top of a costly process was unlikely to prove viable. Hand finishing also went against the principle of automated manufacture. FutureFactories has fastened upon SLS nylon as currently the best option in terms of the balance between cost (process), mechanical performance and appearance. New materials are appearing all the time many of these have caught the eye of FutureFactories in terms of their beauty: in particular ceramic-like epoxies with vivid colour. RP materials development however has been focused on providing high mechanical performance rather than cost. This tends to make them unattractive for RM. It will have to see whether embryonic RM stimulates a drive for cost effective decorative materials.