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DIALOGUE ACROSS DESIGN DOMAINS: RAPID PROTOTYPING IN AEROSPACE AND FASHION

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1. Introduction

Designers take opportunistic advantage of emerging technologies that give them access to new solutions or enable them to design in new ways. Digital technology has become pervasive across all design domains. Designers have historically interacted with very different physical prototypes and subjected these to verification tests; most of this is now carried out using some form of computer simulation. Engineers used to sketch their ideas, generate sketches to visualise the results of their calculations, make wooden mock-ups or have trial parts machined to externalise and evaluate their designs through the process. Car stylists make model cars from modelling clay. Fashion designers made many mock-ups (toiles) in sampling fabrics. While all of this still goes on to a reduced extend, they all now make use of digital tools. Rapid prototyping (RP) technology has renewed the

opportunities for designers from different domains to interact directly and physically with the shapes of objects being designed. Rather then requiring a highly skilled ability to produce samples, often from incomplete design specifications, a physical RP model can be generated directly from the digital model. However using the RP systems themselves requires additional skills. Each RP technology affords different models to be produced more or less easily by it and the different computer software supporting each technology make certain operations easier then others. To date, designers of unusual applications sometimes have to push the envelope of RP to use it to its maximum advantage.

Designers in many fields have embraced the new technology and use it to extend the limits of existing designs. This inherent curiosity of many creative designers drives continuous changes to professional practice in design companies. Designers learn from each other and get inspiration from novel and unusual products on the market. The culture of looking for inspiration is much greater in artistic domains, such as fashion design or product design, but does also occur in engineering design. In most domains the cross fertilisation is limited to similar fields. Companies look at the materials and technologies of closely related fields when looking for technology or features to transfer. For example car companies will study the technology emerging from other car companies very closely. High Street Fashion companies look at the garments of markets leaders for inspiration. While companies do look further afield for ideas for product features, there is rarely a dialogue between the different design domains. For example car companies look at sports shoes for inspiration for car styling and the designers of trainers would look at car styling for inspiration, but there would not be a direct dialogue between designers in both fields. This paper reports on a rare dialogue of two designers who use the same technology, but work in very different fields: the design of turbine blades for aero-engines and the design of fashion garments and accessories. These products are very different: turbine blades are highly optimised safety critical components with long operational lives, while designer fashion is ephemeral and driven by an ever changing context of styles, tastes and consumer preferences. He uses RP in particular for make components of shoes, but also to create fabric like flowing structures. Both fields possess interesting commonalities and differences in their use of rapid prototyping technology.

This paper offers a very brief intro to RP in section 2 and is based on a dialogue between the two coauthors,their reflections on the similarities and differences between their practise and the insights they have gained through their interaction, as explained in section 2, which will summarise the methodology of this paper, in section 3 and introduce the RP interests of both of them in section 4. Section 5 will set up the similarities between both domains and section 6 will outline the differences, before conclusions are drawn.

2. Background

There is an increasing recognition in modern design culture of the importance of a physical interaction with the materials and form of the product in ways that can not quite be delivered by an electronic simulation of the product. Since Schön (1984) the importance of “seeing that” and “seeing as” – the creative reinterpretation of 2D sketches and drawing is well known, now a “feeling of” and “feeling as” to understand the affordance of a form and material is becoming a topic of active research. The role of physical prototypes and the physical interaction with final materials has been addressed from the perspectives of many domains often with roots in human computer interaction design (see for example special issue Physicality and Interaction in Interacting with Computers, Ramduny et al. (2009)).

The ability to explore the possibilities of a medium has to be seen in the context of design processes in different domains. The fewer the constraints placed on a design project, the greater the freedom the designers has to explore the potential design spaces. Therefore this section will look at the creativity in different design domains to set a theoretical context for the work of the different designers and provide a brief introduction to RP technology.

2.1. Creativity in different domains

Research on creative idea generation, such as Finke’s (1990) work on pre-inventive forms – inviting subjects to imagine particular shapes, and then use them in creative tasks – indicates that tasks requiring imagination (but soluble in a wide variety of ways) are made easier by tight constraints that supply elements of solutions to be combined and adapted, and reduce the spaces of possible solutions (see Finke (1992). What these studies of human cognitive capacities imply is that problems requiring creativity are made tractable by the possession of mental representations of the problem and possible elements of the solution that enable the retrieval or construction of candidate solution elements by close analogical matches, and the production of a coherent mental model integrating the solution elements and the external constraints placed on the problem. Developing any new design involves the construction of new and more elaborate mental representations of both the design and the context into which it fits (c.f. Visser (2006)). These are supported by external representations, such as sketches, drawings or prototypes (ref).

Based on a comparative study of 25 testimonies of designers from different domains Stacey and Eckert (in press) argue that different predominant patterns rather then exclusive behaviour exist in different design domains arising from the nature of the constraints under which these domains operate. All domains have pockets needing to identify constraints, resolving over-constraint problems and seeking constraints to structure their processes Constraints on design come from three different mutually-influencing sources:

• The problem that the design must solve or the need that the design must meet;

• The process by which this is achieved; and

• The emerging solution -since making certain decisions will rule out or restrict options for other later decisions.

Artistic design domains, such as product design or fashion design, are typically very under-constrained in the problem that they need to solve. For example, a knitwear designer for a high street retailer might be asked to create a jumper based on the catwalk model of a famous designer. The main constraint on both the process and solution typically is cost and the availability of machine or human resources. As a result, many artistic designers follow a very similar process on each of their projects by which they incrementally set the constraints on their problem. The resulting designs are difficult to evaluate objectively and the designers justify their designs through the emerging context of other designs (Eckert and Stacey, 2001). Uncovering implicit constraints is also an important part of information system design, where designers need to consider the needs of all their possible users and the way these people might understand and use (or misunderstand and/or misuse) the system. By contrast, engineering design is typically over-constrained. To compete in the market, products must fulfil very stringent performance, reliability and cost requirements – but the requirements are often contradictory, e.g. engines must be lightweight and use very little fuel but be long-lasting and produce a high power output. The well-known TRIZ methodology for engineering creativity is based on resolving such pair-wise contradictions between requirements. As most complex products are designed incrementally, companies carry over a significant number of components between product generations, which in turn constrains the numbers of parts that are designed from scratch or reworked. Some engineering components have very long lead times, and their designs need to be frozen early during the design process so that they can be validated and manufactured to the required standard within the available timescale. Components with shorter lead times tend to accommodate any changes arising during the design process that longer lead time items cannot respond to without generating significant rework effort. The longer lead time items often evolve slowly over generations, as the time between the beginning of the project and the committed design definition to design and validate them is very limited.

2.2. Rapid prototyping and rapid manufacturing

There are a number of Rapid Prototyping technologies that allow the direct fabrication of 3D parts from a 3D CAD model. This is not the place to comprehensively review different technologies. Not all technologies are suitable for producing functional parts, due either to the robustness of the parts produced, or the suitability or stability of the materials used, and their roles vary according to the functional requirements of different domains. Laser Sintering describes the process of bonding sand,plastic or metal powders with energy from a laser or an electron beam in an additive, layer-by layer build process that is directly controlled from a CAD model. Compared to traditional manufacturing methods the main cost implications are formed by the build volume and the capacity of the build system to manufacture exactly what is required within specification limits and with an acceptable yield. The higher the level of functional integration within a single part (i.e. the more parts that would otherwise be formed separately and mounted afterwards), the higher the economic advantage for RP technology.

RP has been originally developed for prototyping as the name implies, but users soon saw the potential to use it in direct manufacturing for components where personalisation or customisation make it more cost effective than producing tools for one-off or low volume production, and where suitable materials are developed for the application, as in the case of medical (eg. dental implants, hearing aids) and design objects (e.g. sunglasses, light shades).

3. Background of this paper

Designers in different domains often work in isolation from each other. This paper reports on a deliberate effort to bridge this gap by bringing an engineering designer and a fashion and textile designer together and allowing them to discuss their use of rapid prototyping directly, after many conversations that the first author had with both of them separately, and analyzing systematically what their concerns were.

3.1. The conversations

The first author had several informal discussions with both designers about their respective processes with Philip Delamore in the context of the Considerate Design project (Black et al., 2009), where both were researchers, and with the engineer as part of his doctoral research on process modelling. This paper is based on a conversation between the authors in October 2009, which was preceeded by a guided tour through the company's RP facilities. The conversation was recorded, and transcribed. For this paper, the conversation was grouped in issues, which will be presented as similarities and differences, in the following sections. The quotes in this paper are derived from the conversations. Quotes by the engineer are in 10pt font normal script and by the fashion designer in 10pt italics. The analysis was shows to both of them and discussed with them. The two designers afterwards had another meeting, where the engineer was shown the fashion design facilities, followed by several informal conversations. These have informed their reflections in section 6.

3.2. RP in Aerospace

The use of RP prototyping in the engineering company has traditionally been motivated by the desire the evaluate designs as soon and as thoroughly as possible, as late changes to the design could compromise cost and product delivery schedules. The companies employs sophisticated computer simulation technology to model their product and carry out as much behavioural analysis as possible before committing to producing production components. These are then subjected to rigorous tests to fulfil certification requirements. Different engineering departments are now looking at producing prototypes with RP technology at earlier stages of the design process to elicit improved feedback about the evolving design. This will enables them to bring in company experts who find it much easier to assess physical aspects of the product in a physical prototype. For example lines of sights can be very important for inspection during manufacture and hard to assess when components are modelled separately in different CAD packages. Increasingly engineers are becoming aware of the potential of using preliminary models early in the design process to obtain informal feedback on conceptual designs, so that they can explore a wider section of the design space more easily. Figure 1 Airflow through a cooled turbine blade (from Rolls Royce, 2005) For example the co-author is involved in the design of turbine blade cooling systems, where the correct distribution of cooling air through is vital to assure the robustness of the entire blade. The air flows through the hollow spaces within the blade, removing heat from the metal by forced convection. It then exits the blade through small holes that produce a thin film of cool air over the surface of the

blade, protecting the blade from the full heat of the main gas path. These were traditionally designed using a series of 2D drawings of sections through the blade. Expert engineers would mentally assemble the segments into a 3D space. Now RP enables them to produce solid models of the cooled blade and also of the cooling space. This makes it easier to check that passages have appropriate shapes to support the required flow of cooling air.

"Well it's one of the critical parts of the design, research elsewhere suggests that when you are designing your turbine blade the two things that you ultimately care about are, where does the flow go, are there any stagnant regions inside the blade" The RP model services as a boundary object between different groups of engineers, something they can all understand and relate to and which enables them to discuss the problem from their own perspectives. "And what is interesting is when design teams sit down and they use one of these to mediate their conversations. If you have a casting expert, a design expert, a lifing expert, everyone who really knows and they are communicating using models like this, then history has shown that you can cast complicated new designs with high yields right from the beginning because you trap the problems at a very early stage and you make them go away."

To obtain a RP model the engineers request it from the RP model production group, who look after a number of different RP technologies and translate the requested design into a representation suitable to produce RP models. The engineers don't directly interact with the RP software and don't see how their model is made although they all understand the basics of the process. At the moment the resource is available to all teams, but the uptake varies between teams, according to the their experience of and the specific challenges of the component that the team is designing.

3.3. Example of RP in Fashion

The use of RP technology was introduced by the second author to the London College of Fashion as part of the integration of a range of digital technologies to develop the research and development capabilities of the department, and also to integrate and support the curriculum development. The use of RP in the fashion industries at the time was primarily in the sports footwear sector where large numbers of sole units were being produced for design communication and assessment. The ability to produce sole units directly form CAD was seen as advantageous as these would traditionally be made from wood and/or wax and each would take on average a week to produce, and up to eight iterations might be required. Most of the large sport shoe companies adopted this practice. Through a number of research projects the author developed knowledge and contact with users across a number of design domains using RP technologies and also established contact with the technology developers. This knowledge was disseminated to a wide range of students in footwear, accessories, costume and fashion disciplines, and as a result a number of students began to explore the creative opportunities offered by these new design freedoms. New titanium sintering technology, developed by a technology vendor for medical devices, who supports the creative use of their technology through sponsorship to designers, was made available to footwear masters student at London College of Fashion (LCF) for the building of several heel prototypes with the technical support of the staff of the Digital Studio at LCF. Several designs were developed which demonstrated the potential for such technology in the footwear market. The designfreedom of titanium sintering allows complex designs which would be difficult or impossible to build using traditional casting techniques. The materials allow lightweight yet strong designs, which use less material than traditional techniques. The result was a one piece heel and shank which plugs in to a nylon sintered sole, which. reduces the number of components. The process began with a design tutorial with the student who was having difficulty in modeling a complex heel using traditional metalworking techniques, and was interested to find out if RP techniques could provide an alternative. From her sketches for heels two designs were selected for development and she was assisted in the CAD modeling stages of the heel. This process was rather intuitive and based entirely on the aesthetic requirements of the student, without any dimensional or mechanical consideration. Several physical prototypes were made in plaster on a 3D printer to check for pitch and fit to the last prior to sending the CAD file to be built in titanium. It took several attempts to build successfully but was a valuable exercise for both technology developers and designer alike. Strength tests were subsequently undertaken and the heel was found to be capable of supporting more than 400 kg, which was well beyond any expectation, but this was not a consideration at the design stage.

The outcome, see Figure 2, is that the first design prototypes have been successfully made into shoes and exhibited in the student degree show. As a result the shoes have been shortlisted for two design awards and the technology suppliers have an interesting case study which demonstrates the potential for this material process in new markets, and useful marketing prototypes which can be used for trade shows and promotional materials. The heel displayed in Figure 2 is not just a test piece for this the rapid prototyping technology, it is also a fashionable item, which keys in with current cat walk fashion for interesting shapes in heels. The shapes are organic and flowing. The design of these heels is interesting as an art object, just as much as an example of a new technology. During the design process observers reacted to the visual quality of this organic and praised the emerging design for its aesthetic qualities. In this sense the design was a success even before its structural qualities were tested. The playful nature of the design process and aesthetic considerations were the drivers without constraints of cost or mechanics. However, the actual cost which would be around $2000 is still acceptable in the couture market, so that the product is potentially viable, and alternative materials are also now being tested which would reduce costs and make larger volume production possible Figure 2 Rapid prototyping model of the heel, final shoe and sketch above In fashion the interaction with the medium is much more direct then in engineering. The co-author works as a designer directly with the RP software and explores its potential. He keeps up to date with technological development and directly in tough with several RP technology producers. Students or other designers interact with an RP technician. As we have argued in Eckert and Delamore (2009) the culture of fashion design is very encouraging to trying out and exploring new materials, tools and techniques. This exploration is often playful, rather then being goal directed. Fashion is traditionally a subject that takes inspiration from all sources, so that the results of exploration can be incorporated.

I think for us at the moment we regard it as a sort of curiosity and a novelty and most of our interaction in terms of getting things made Fashion designs are not safety critical (within reason) and has few hard constraints, so that many ideas and concepts can be used. For example the co-author is exploring using recycled power from past laser sintering cycles, which is usually discarded after each pass, because maximal bondage can't be guaranteed. Since this is not required here, the material can be used much more efficiently.

4. Similarities

While the products that are produced by both designers are rather different, they agreed on many of the advantages of using RP technology, but also on some of the challenges that they faced with it. The main opportunities lie in improving the design process through providing individual designers and teams with physical objects they can interact with, while the challenges lie in persuading people to change the way they are working.

4.1. RP in individual use

For both of them the immediacy of the 3D object plays a very important role in their processes. It enables them understand and explore parts with would be much harder to achieve with an electronic simulation or take much longer (and be more expensive to produce), with a traditional wooden model, who production was a highly skilled task and limited to certain classes of designs rather than the (relatively) unconstrained designs enabled by RP methods. With the clear one of course the first thing is hold it up to the light and understand what is going on inside it, it gives you a picture of how does it work …. And you can feel comfortable with that and you can understand what is going on and that's all very nice …. Yes this is a 3d representation of a stress model and they can understand and interpret. ….It's not the same to see it there, to actually have it in your hand and realise that actually there might be a flow of stress moving around like this, isn't it interesting that there is something you can see, the pattern in 3d will be integrated altogether in your head.

Both feel strongly the being able to interact with the 3D form unlocks tacit understanding which would be difficult to express explicitly or two construct from 2D representations. This is often associated with the exact shape of curve or the relative position of different design elements. In engineering a formal simulation and physical testing will always follow, but experts have built up a lot of experience about the details of the form and how they interact with the function of the product. "It's helpful if you have got an expert who says that it just doesn't feel right because he has had 40 years of core production, and even with a plastic mock up he thinks it bends just a little bit more than he would be happy with."

Mapping from 2D to 3D has a long tradition in both domains. Engineers have been using 2D schematic drawings and fashion designers make cutting patterns. The translation to the 3D shape occurred in the mental models of the engineers and fashion designers, so that much of the checking of features of the designs happened in their heads and was difficult to share. It therefore required considerable trust in their professional skills. In both domains some experts mainly work in 3D, as do for example manufacturing engineers. RP changes the division of labour between different groups of engineers. Now designers who have traditionally worked in the 2D can themselves create the 3D shapes and translate them, where they would be traditionally left this translation to the test or manufacturing engineers. In fashion the option of modelling toile fabric on a 3D stand has always been an option, however, it does introduce an additional step from 3D toile model to 2D cutting pattern to 3D garment sample. Both designers felt that one greatest advantages of RP is that the component can be produced in the right scale. A distorted scale is a great hindrance to unlock this tacit understanding of curves and proportions The trouble with computer models is assuming everyone has a screen of about A3, all components are A3 and all green. If designers work only with a computer model of the design, they can be tempted to optimise the computer image rather then the design itself. They might therefore spend time on unnecessary details, which play a different role at the required size.

I think also the decision making process where a designer will tend to fiddle and tweak and play on screen almost at infinitum with the design to try and aesthetically finish the process and I always encourage them to print an early model see what it looks like and feels like. As soon as they get something physical out of the machine immediately they are making decisions about it very quickly and then they're then able to go back and apply those to their on screen designs.

4.2. RP in the organisation

Both designers commented on the role that RP models can play in supporting communication across a team with the wider organisation. The immediacy of interaction affords far better communication and design decisions can be revised before significant resources are committed. In the case of fashion this communication can also reach to the customers, who might not be able to provide feedback on a 2D representation, but can picture the final product from a RP model or can try on an RP component for fit.

But you obviously get into the… there is an opportunity, which is not rocket science, where the design team will come up with something and they do work pretty closely with manufacturing they can always work better if they work fairly close. You can take it down to a manufacturer and say can you make that, and the guy will say "well I can't make that but if you change such and such then I can make it". While understanding a RP model does not generally pose a problem, both designers commented, that people sometimes recognise the skill required in generating an RP model and might not value the effort that has gone into generating the models. I think very similarly there is a lot of resistance, we certainly find that a lot of the, both the tutors that are teaching and also the technicians who are responsible for the traditional practices within fashion and making have a perception that we have these sort of photocopiers that you press a button and something pops out and that is to do, there is no craft in it and there is not necessarily any skill in it, eroding traditional skills.

One reason for this might be that digital literacy is still not universal. Older fashion designers or engineers have been trained with 2D methods and find it difficult to adjust to a 3D way of working, inparticular, if it is not required for their particular role in the organisation. In fashion design there is also the additional problem that the students, who make use of the RP technology might not be familiar with 3D thinking (students, who come form a print or weaving design background tend to work primarily in 2d)

Actually we are guiding them through most of the process because nearly all the students that are coming to us have no 3d skills. Many of the similarities in the use of RP arise from the general advantages having access to a 3D technology, where the differences arise from the way it is employed in the context of the domains.

5. Differences

Access to RP technology is very different in the two domains. While employees of engineering companies generally can request RP prototypes, if they can argue the need for it, they rarely have access to the technology themselves. It is produced for them by specialists. The engine company has a dedicated team of RP specialists using a variety of different technology, but only a small group of engineers in the organisation works closely with them and therefore knows about the capabilities. They still don't use the RP software themselves. The fashion designer by contrast uses the PR software himself and operates the RP machines. He sees a direct link between what he does and how it comes out. He is motivated to push the limits of the software that he understands well, because he can see the benefit himself. For example he developed link structured gloves made from tiny interlinked rings, similar to medieval chain mail, where the challenge is considerable to get all these tiny rings to be free moving in all directions. To achieve this he worked with a computer scientist using genetic algorithms. Fashion designers are much less concerned about how something is generated, as long as they achieve the effect they wish to have. They can be flexible, as the constraints are much less rigid. In the engineering using tried and tested means of product is an important risk reduction strategy.

I think what is totally different when we are perhaps designing or using any of these technologies we are trying not to think about the technology, trying not to think about the limits imposed on any particular system on how we make something. Yes. It's simply purely the design and once we have created the design it's then a matter of either plugging it into an existing system that we know within the fashion industry or increasingly looking outside the fashion industry to find out what other people are doing like engineering and aerospace and medical which can offer us new solutions. Being subject to much less stringent constraints fashion as an industry can be more opportunistic about the materials that is uses and the properties they need to have. By contrast engineering has very tight requirements on the components that are produced. Only if materials have exactly the right characteristics and this can be proven, RP can be employed as a manufacturing technique or be used to replace production prototypes.

RP technology plays a different role in the two domains. In engineering RP is still mainly used for evaluation purposes during the later stages of the design process, where it is pushing its way forwards into a tool during early design. In fashion the main roles lies in rapid manufacturing of parts which are either customised to individual measurements or are produced in small batches. With the catch of manufacturing techniques like injection moulding rapid prototyping is economically viable for some of the typically small batch sizes in fashion. One of the long term visions behind RP technology in fashion is to send RP programs through the internet and produce fashion products with a localised desk top printer. The generally opportunistic attitude of many fashion designers, makes them open to new technology and as creative fashion designers typically work independently or in small team, they don't have to persuade a large organisation of adapt new technologies or change the way they are working. By contrast introducing new technology into complex engineering companies brings considerable challenges, as many more people need to be convinced and new technology requires new processes, which in tern need to be integrated into other existing processes. Another difference between the two designers lay in their interpretation of RP as a craft skills. For the fashion designer RP was one of many techniques that he employs. He sees it largely as his chosen craft medium, which is complementary and employed together with other craft skills. It's a meeting of the tacit knowledge and understanding the craft skills with challenging those at the same time. Whereas the engineer was concerned that RP is another step away from the craft skills that have once been available in the organisation with the traditional wooden model makers. But also engineers would benefit from a direct interaction with materials, rather then something that is electronically mediated.

I'm wondering whether making less use of our craft skills has in some way limited out creative vision and voice. …By craft I mean practical doing things skills. I mean actual getting your hands, doing the kind of work where you actually have to wash your hands in the sink under a tap when you have finished. Again these differences might have arisen from the way the technology is used rather then from the scope of the technology itself.

6. Learning from each other

This section reports the insides that both designers have personally gained from the interaction with each.

6.1. The engineering designers' reflections on fashion practise

Of particular interesting was the commonality of the benefits of using RP technology, but also of the usage issues between two entirely different design domains. From a practical perspective it was interesting to see the operational problems that the fashion designer faced in producing RP models, Specifically, the machines require careful adherence to procedures and regular cleaning and preventative maintenance. This must be managed and can't be wished away.. Casual users appear less interested in this necessary aspect, and prefer rapid access to parts rather than involvement in the production process.

It was striking to see the range of novel biomimetic and engineered shapes that had been produced purely as the consequence of playful design, where they had served as inspiration, rather than as that of an active search for new solution principles. Seeing them produced could change the perspective on how to seek radically different engineering designs, by creating new forms and later identifying useful derivations or applications of them. Using a 3D haptic pen system for defining forms made clear how simple it can be to unleash creativity and allow design imagination to flow freely.

Within the Fashion Design world as described, the prejudices of potential new users and their alienation by using a computerised method to create designs was the perfect mirror of the engineering world, where designs are evolved almost exclusively using electronic definition methods, and where there can be a strong reluctance to approach the task from any alternative direction. This can make it challenging to introduce alternative techniques to enhance design creativity rather than evolve existing designs. In one domain, i.e. fashion, electronic definition methods can be regarded as cold and frustrating of creativity -in the other, i.e. engineering, free-flowing definition methods can be regarded as lacking in rigour and likelihood of delivering a solution of sufficient quality.

6.2 The Fashion designer's reflection in engineering

One of the most striking aspects of the discussion was how craft oriented the development of these highly technical engineering parts is, and the role of physical touching and feeling, tacit craft skills which would perhaps be much more readily associated with crafting a piece of clothing. On the other hand most of the design tools that we are adopting were developed for engineering applications and there are few which allow this haptic interface with design. Most software tools tend to be based around linear measured additive generation and are difficult in this respect for a fashion designer to enter the design space where nothing is familiar. In the case of making hard products we can see much more similarity between the fields, as in the example of the heel, and in applications where we need to have biomechanical input for example, or where engineering systems give the benefit of simulating physical materials properties using Finite Element Analysis. In the case of clothing however where we are dealing with the interaction between cloth and body, and the many components and interactions between components which are variable over time and with motion we have a very complex system in the case of producing CAD simulations and physical prototypes. In this case I think there are many possibilities for cross-disciplinary interactions, and much potential for innovation in materials and manufacturing processes. It is invaluable in discussing the similarities and differences between domains that we are also delineating a new space in which these discussions may take place, and from which new solution spaces may emerge. The example of textiles and RP is an interesting example if we consider that the development has been directed by the available materials and processes which were developed for engineering applications, and where the technology developers have not even considered the fashion domain in the development of these materials and processes. The creative use of these has however opened up a platform for the engagement of a wide variety of disciplines where the RP technologies have inspired creative users to engage and challenge existing practices. This is primarily through the ability for designers to physically interact with the process of producing the prototypes in a studio environment where tacit decisions and round-table discussions can quickly allow engagement with the physical object.

Conclusions

While many of the findings about the use of RP in industry might not be surprising to experts in the use of rapid prototyping technology, the similarities and differences were interesting to the two the participating designers, which both understood their own processes better through talking to each, but also saw the other ones practise as an inspiration for their own work.

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