

CURIOUS DIRECTIONS FOR PRODUCT DESIGNERS: HOW TECHNOLOGY IS AFFECTING MEDICAL DESIGN PRACTICE

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ABSTRACT

Medical product design practice has changed over the last five years as advances in technology, both digital and practical, have opened up new opportunities to address patient needs in innovative ways. This paper identifies examples of new practice, considers how the role of the medical product designer has responded to the web of advanced technologies impacting communication and production, and suggests directions for product design education to build collaboration and project work to provide students with the transdisciplinary understanding, skills and knowledge they need to meet these specialised industry demands.

Keywords: 3D printing, software, medical, health

1 INTRODUCTION

The product design profession has developed incrementally since the first industrial revolution, with advances in technology building on previous practice, adding successive chapters on design for production. Ideas and values have changed, influencing design directions, with sustainability in particular impacting design through consideration of product lifecycle in design, however, the underlying body of knowledge that informs the discipline has expanded cumulatively, at least until recently. In the last five years that has begun to change as advances in digital media have broadened the scope of the Product Design discipline, and continue to do so. Yet to meet these emerging opportunities, Product Design educators are recognising that the accumulated knowledge and practice, in particular in relation to production, needs to be revisited with a fresh perspective that responds to being a designer now, in a digital world, as opposed to previously when the impact of digital media was essentially limited to computer numerically controlled manufacturing.

Design for health projects provide a particularly interesting example of how advances in digital technologies are opening up new directions for product designers and creating new collaborations, in this case between clinicians and designers. Medical researchers and practitioners have strayed into territory that could be deemed product design as the 3D digital technologies recently developed have been championed by clinicians in direct response to their needs in treating their patients, whilst product designers are equally finding themselves involved in medical based product design that challenges conventional practice.

2 DIGITAL TECHNOLOGIES

The main digital technologies that are impacting medical product design are in softwares that supports the manipulation of 2D to 3D scan data; digital communications tools such as Apps; and 3D printing. Apps, for example, are providing designers with new opportunities for communication that are being used in service design for health that are innovating practice. These are predominantly focussed on supporting health management and nursing care, with communication and health data tracking particularly prevalent. Whereas there has previously been a division of labour between the design of the product and the digital component, students are now working across boundaries as technology makes digital drivers more accessible [1].

The development of 3D printing for medical applications has influenced the development of the 2D to 3D scan data manipulation software over the last twenty years [2]. 3D printing itself is a term that refers to a range of production processes that build objects from the ground up, in layers, without the

need for tooling such as moulds [3]. Technically known as additive manufacturing, these technologies are driven by 3D computer models, and can use single or multiple materials to build forms. The most basic form of additive manufacturing is fused deposition modelling which is essentially a filament of material, most commonly a thermoplastic polymer, extruded through a heated print head mounted onto a stepper motor with a heated platform for adherence, that lowers incrementally to allow for the build. These machines can extrude multiple materials for increased complexity, particularly through the use of soluble materials that works with the part material to create scaffolding to support undercuts and complex internal geometries in the model. Fused deposition modelling is used in medical projects predominantly to build planning models. These can also be constructed from cellulose based materials in a powder form that is fused using a binder extruded from a series of print heads, much like a 2D printer. These models are less permanent than those created by the fused deposition modelling machines, which tend to print in acrylonitrile butadiene styrene (ABS), but for medical planning applications this is not usually an issue. There are engineering grade printers that work at a micron level to print UV cured resin supported by a wax scaffold that are used in medical product design applications and in this case the part / support material can be reversed so that the wax can be printed for casting applications, used in conventional medical product design.

Medical applications predominantly use metals in the print, in particular titanium in a mesh form designed to allow human cells to grow into the structure. The titanium is powdered and laser fused in a process called direct laser melting, that is similar to selective laser sintering except that it is a cold process, whereas polymer based selective laser sintering takes place in a heated chamber. This difference has significant implications in relation to the importance of software that enables the user to work directly within an actual STL file, manipulating the design to reduce post processing. This is vital for metal processing, as the cold chamber means that the remaining powder does not act as a support structure (whereas it does with heated polymer powdered 3D printing) meaning a scaffold will be printed with the part, not dissimilar to that in fused deposition modelling. As post processing of metal is currently labour intensive, it needs to be reduced to the minimum.

All additive manufacturing technologies create objects without the need for a preformed mould. This lack of upfront investment means that customised products can be created. This single factor has the most impact on innovations in medical product design and implications for designers working in the field as customisation for individual patients is the ideal for any medical design application. In addition, fundamentally more complex objects (particularly in regards to internal geometries), tailored to an individuals needs, can be developed than previously, as even multiple-part moulds must be designed taking into account the path of the tool tracking out of the object. For medical project design work, both internal and external to the body and in respect to customised instruments for example, the complexity and individualisation that 3D printing now allows, and the sophistication of the suite of softwares that support the manipulation of 2D to 3D data blur the boundaries between disciplines.

3 MEDICAL PRODUCT DESIGN

For direct medical applications and more broad healthcare product designs, from implants to customised hearing aides, working with software that enables the translation of 2D scan data into 3D forms is the starting point for most objects to then be physically produced using 3D printing. Because of this, it has been medical practitioners who have been the early adopters of the software and subsequently driven the 3D printing of medical products, not Product Designers. Yet this practice means that the proven capabilities of Product Designers in user design, creative problem solving and optimising product design for production are not yet utilised.

One of the most significant areas of changing medical practice that is providing new directions for medical product design, is in surgical planning. The development of surgical guides for complex situations is a cross over between medical and product design. Currently it is the realm of interested medical researchers, rather than product designers, but collaboration with product designers would potentially provide innovative approaches to the design and construction of the guides that could move the development of the application forward. Dr Raphael Olszewski is one of the leaders working with 3D printing and scanning to develop a method of surgical planning for complex procedures. He scans the patient's bone, constructs a 3D computer based model of the bone from the scans and 3D prints out multiple copies of the bone on which he can practice his surgery. Once he has planned the best surgical procedure, he develops surgical guides that are also 3D printed, that can be inserted onto the bone to ensure the cut is accurate to the planning [4].



Figure 1. Surgical guides are developed using 3D printed practice bones and 3D printed (photo c J.Loy)

Developing surgical guides is becoming increasingly complex, as their potential is explored for multiple applications. Informed collaborations between Product Designers and clinicians to consider the operation as a whole, rather than the guides at their most basic functional level, could potentially result in evolved surgical tooling that supports the process of the operation as well as precision placing of cuts and implants.

3.1 Mechanical support structures

Human exoskeletons have been used for adult patients affected by conditions such as arthrogryposis multiplex congenital that cause stiff joints and under developed muscles, to help the patient to move more easily. However, these exoskeletons are complex mechatronics and there have been restrictions in what it has been possible to make for younger patients. Researchers Rahman and Sample work on mechanisms to support movement in patients with neuromuscular weakness due to muscular dystrophy or spinal muscular atrophy [5]. They developed an exoskeleton called WREX that was fitted to a wheelchair and suitable for children as young as eight, but had to push the boundaries to develop an exoskeleton to fit a two year old, Emma Lavelle, who was not restricted to a wheelchair. 3D printing allowed the researchers to scale down an exoskeleton in weight and size to fit [6]. This innovation suggests new directions for mechatronic design for engineers and product designers to work in, to problem solve in ways that were not previously possibly to functionally address.



Figure 2. 3D printing is providing new opportunities for medical product design of exoskeletons (photo c StratasyS)

Product designers can contribute to this field of work by bringing the user interaction, experience mapping approach embedded in the discipline and also the creative thinking based on situation design approach to problem solving in this area that clinical researchers are not specifically educated in. An example from a medical product design that illustrates this point is in the development of the Jaipur Knee [7]. The Stanford-Jaipur low cost prosthetic knee was designed by the Stanford University, USA, working with the BMVSS team and hailed by *Time* magazine (issue of November 23, 2009) as one of the 50 Best Inventions of the World in the year 2009, yet it was initially engineering driven rather than situational design driven. The initial design for a low cost prosthetic knee focussed on mechanical function, and less on the user experience or cultural referencing. The knee initially clicked during use, forcing users to adapt the mechanism, and was not suitable to be used in the squatting and

cross-legged sitting positions favoured by the Indian population it was designed for. These are issues that a product design approach to initial user research informing design could have prevented.

4 MEDICAL IMPLANTS

These applications build on the skills required for the surgical guides to create medical implants using 2D CT scans that are constructed into a 3D model. The morphology of the organic material is mapped in the process, and gaps in the data – which are currently inevitable in the translation of the 2D scan data into 3D data – bridged in the modelling. An example of this is the development of a replacement hip joint. This is not a straightforward exercise, as the joints can be degenerated, for example due to tumours that have been removed that have affected the topology of the joint.

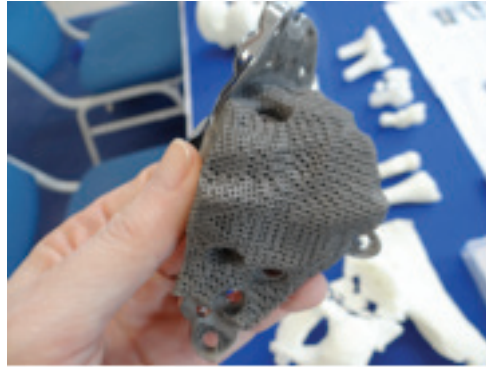


Figure 3. Titanium hip joints, such as this one, can now be 3D printed in complex geometries that are customised to match the patient's remaining bone (photo c J.Loy)

The surgeon must make decisions in relation to the development of a replacement joint that can potentially move across into product design with the innovations possible with 3D printing, that allow for multiple part assemblies that can conceivably change not only the form of replacement parts but also more radically the development of innovative replacement joints. This is particularly interesting for the replacement of complex joints such as ankle joints. If the ankle has been severely broken patients will develop a potentially debilitating arthritis in that joint approximately five years after the initial break. Currently the treatment for this is to fuse the bones in the ankle, which results in a lack of mobility in the joint. This restricts the patient's movement impacting involvement in certain types of sports, such as surfing. This is an area of research that Product Designers could significantly contribute to as current research suggests that dynamic medical modelling and 3D printing opens up the possibility of redesigning ankle joints, as illustrated by the work of Panagiotopoulou on comparative locomotor mechanics [8]. Joint design based on 3D printing could potentially move beyond copying the action of an original joint, but rethink it, particularly in relation to a specific task. Product designers in collaboration with medical researchers could significantly contribute to this area of study.

5 NEW DIRECTIONS FOR PRODUCT DESIGNERS

Medical practitioners have been the early adopters of the 3D printing for medical applications because of the starting point of using CT scans for the construction of 3D forms for implants and, for example, skull plates so if Product Designers are to maximise the potential this starting point provides, design education will need to provide students with the digital skills to work with CT scan data and STL manipulation (these are the files produced specifically for 3D printing that it is possible to optimise and adapt for production with dedicated software) that medical practitioners are developing as well as an in depth understanding of the hardware for 3D printing. Product designers can then bring their innovative practice, based on user centred, situational design research skills, to collaborative practice. There are examples of emerging practice by product designers that are responding to the opportunities that digital media innovation is providing for medical projects. For example, emerging practice shows that product designers are working with clinicians exploiting the application of 3D printing technology in the customisation of product for design and health applications. An example of this practice is the work of Bespoke Innovations™, Inc. This company was founded as a collaboration between an Industrial Designer and an Orthopaedic Surgeon. Their stated mission is to 'bring more humanity to

people who have congenital or traumatic limb loss' [9]. This product design company developed individual prosthetics for their clients to meet their emotional needs as well as their individual functional needs; for example, the design of a leg prosthetic for a footballer, or a cyclist differs from the leg most suitable for a motorcycle enthusiast. This level of customisation allows for innovative thinking, such as designs that go beyond replacement into enhancement.



Figure 4. Bespoke Innovations product designers use 3D printing for customised prosthetics (photo c Bespoke Innovations)

For product design educators, preparing students for work on emerging medical design applications, based on innovations in digital media, involves not only helping them to develop new practical skills to an advanced technical level but also develop specific relationship skills aimed at promoting effective collaborations between designers and clinicians. Promoting a shared language, culture of design development and understanding of practice will support genuine collaboration, over a clinician / technician relationship, that is more likely to lead to innovation. It does require commitment, but there are opportunities emerging that suggest it will be a worthwhile development for product designers for the future, taking their work in unexpected directions. Fripp Design and Research is an example of a product design consultancy exploring these new, collaborative directions. Fripp Design and Research is a Sheffield based consultancy who work with the University of Sheffield and the Wellcome Trust to develop improved soft tissue prosthetics from a user point of view [10].



Figure 5. Fripp Design and Research collaborate on the design of 3D printed soft tissue prosthetics (photo c Fripp Design and Research)

6 CONCLUSION

3D printing is changing the role of the medical industrial designer by creating new opportunities for supporting health and wellbeing in a curious range of applications. The involvement of product designers in design for health tends to be service design based projects, such as way finding, and the design of practical equipment dedicated to specific tasks within the clinical environment. The practice of designers in this area has developed within the discipline generally in much the same way as commercial product design, with designers working with clinicians and users to create product responses to problems working within the conventional parameters of production and marketing. Product designers have still needed to meet a market based on mass production or at the very least

batch production conventions in order to be viable. It is a particularly demanding area of design due to the regulations the designer must be aware of and work with. Design practice has been refined in these areas with specialist consultancies emerging, but their work has been constrained by the commercial restrictions of the industry. Because of this, product design has to compromise in its service to this industry, resulting in products that meet the needs of a broad percentile of the users in situations where bespoke, innovative products would be the ideal.

The last five years have seen dramatic changes in production potential for specialised products, with 3D printing (technically called additive manufacturing) emerging from a prototyping technology into a technology for direct manufacture. This is transforming the relationship of product designers and clinicians, and suggests new directions for product design education to meet the opportunities and requirements of this new relationship. Technological developments are bringing the digital and the physical together in new ways that are challenging the nature and scope of the traditional project work in this area for medical based product design, and so will impact future directions for curriculum planning. To understand the opportunities and anticipate the needs of graduates to maximise those opportunities in the future, examples of innovative practice are described, though currently these are often developed by clinicians learning 3D computer skills and aspects of product development, rather than product designers themselves (although this is not always the case), suggesting the potential for further development with the direct involvement of trained product design innovators in the future.

For educators in Product Design curriculum development, the implication of these developments is a review of traditional design practice teaching. If Product Design education were to be proposed and developed as a new area now, rather than as an evolution of an existing discipline, then based on the emerging opportunities illustrated by the examples in medical design, digital media would take a more significant role in the curriculum and the designer would be positioned as a collaborator providing interactive morphology rather than fixed, resolved outcomes. As additive manufacturing eliminates the need for investment in tooling, the relationship of the designer and client shifts into a new paradigm. To maintain its relevance, Product Design in higher education will need to shift with it, or risk being subverted by more flexible market providers.

REFERENCES

- [1] Student work presented at Design Health Symposium Auckland University of Technology 12-13 December 2013. Accessed online on 23.02.2014.
<http://autproductdesign.wordpress.com/2013/12/11/dhw-lab-designhealth-symposium/>
- [2] Chandra, A., Watson, J., Rowson, J.E., Holland, J., Harris, R.A., Williams, D.J., 2005 Application of rapid manufacturing techniques in support of maxillofacial treatment – evidence of the requirements of clinical applications *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 219(6), pp.469-475.
- [3] Gibson, I Rosen, D Stucker, B Additive Manufacturing Technologies: Rapid Prototyping to *direct digital manufacturing* 2010 (Springer: New York)
- [4] Olszewski, R., Herve, R. Clinical Applications of Rapid Prototyping Models in Cranio-Maxillofacial Surgery 09/2011; In book: Advanced Applications of Rapid Prototyping Technology in Modern Engineering Source: InTech
- [5] Housman SJ, Le V, Rahman, T., Sanchez, R.J. Reinkensmeyer, D.J. Arm-training with T-WREX after chronic stroke: Preliminary results of a randomized controlled trial *Proceedings of the 2007 IEEE 10th International Conference on Rehabilitation Robotics*, June 12-15, Noordwijk, The Netherlands
- [6] Accessed on 23.02.2014 <http://www.stratasys.com/resources/case-studies/medical/nemours>
- [7] http://jaipurfoot.org/what_we_do/prosthesis/stanford_jaipur_knee.html#.Uwlfx16nBLE
Donaldson, K CEO of D-Rev, accessed online 23.03.2014 <http://d-rev.org/>
- [8] Warner, SE, Henry, V., Roskilly, K. Hildebrandt, T., Panagiotopoulou, O Regional variation in digital cushion pressure in the forefeet of horses and elephants *PeerJ Preprints* accessed on 23/02. 2014
http://scholar.google.com.au/citations?view_op=view_citation&hl=en&user=dEHFfWAAAAAJ&sortBy=pubdate&citation_for_view=dEHFfWAAAAAJ:WF5omc3nYNoC
- [9] Bespoke Innovations <http://www.bespokeinnovations.com/>
- [10] Fripp Design and Research accessed on 23.02.2014 <http://www.frippdesign.co.uk/problems-solved/the-wellcome-trust/>