From Hardware to Wetware: How Sericulture Could Shift our Manufacturing Attitude in an Age of Biotechnology

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ABSTRACT
This paper examines Slow Technology in the context of biotechnology, design and craftsmanship in order to speculate on the potentiality of innovation. The overlap in disciplines will be demonstrated through the example of Biophilia – Organ Crafting. Genetically modified silkworms, raised by organ craftsman, would weave individual scaffolds for human replacement hearts. Such novelty in the silk industry could establish high-tech-applications - not solely in the biomedical field, but also in the consumer products market, allowing for the development of biodegradable products. The example of the future craftsman is used as a lens through which we may understand the value of, and today's potential for, manual work as well as its importance for our communities.

Author Keywords
Genetic engineering, tissue engineering, silkworms, silk scaffolds, organ replacement, future craftsmanship, novel industry;

INTRODUCTION
The facets of socio-cultural and economic life implicated in general production and consumption are intriguing. How do they converge at the very centre of innovation in biotechnology and design? Thus, I am interested in examining the history, causes and the potential inherent to this 'felt' of influences particularly through the effect of time, interaction and human factors.

As a designer fuelled by an interest in scientific method, that are both emergent and at the experimental stages, I am also aware of the controversy - especially with regard to synthetic biology and genetic engineering. This means confronting ourselves with endless strands of fears and deeply human questions. But is there perhaps a way we can interact with a controversial technology in an acceptable way? What if this technology even holds solutions to improve our deep human desires?

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CONSIDERING SLOW TECHNOLOGY NOT JUST AS OPTION - MORE OF A REQUIREMENT
The idea of translating fossil- fuels into locomotion or transforming it into goods comes across as self-evident today, but may have seemed very odd when it crossed our minds for the first time. It is important to understand how some technologies have been established, and to continually highlight the reasons why one direction of development has been pursued and while others have not. We tend to forget, that the main reasons for our technological-societal progress were laid in an age when smoking whilst being pregnant wasn't seen as dangerous and the usage of DDT was encouraged, as it was seen as "so safe you can eat it" [1] [2]. Industrialisation cut former complex work cycles of knowledge into smaller chunks of simpler tasks, to then being either given to less qualified people or even performed by robots.

The consequences of the older values are present in our all lives and can be even seen as a *cultural lag* [3]. The circumstances have shifted to extremes: Individual mobility for instance was once a luxurious form of travel, to then revolve into a mass phenomena, if not an autocratic, economic force that we are willing to obey.

The invisible cost of fast production lines is broadly disregarded, as processes happen invisibly or the parameters are simply not indexed in a money-based value system. In fact our fixation on abstract values like money, which has seemingly rendered our societal progress, has blurred our view and appreciation for tangible experience.

The concept of *grey energy* might dictate in the near future how valid innovations really are, optimising only the time-string. Blissfully ignoring how suitably it nestles itself into the stakeholder system human-nature-resources, it will be disqualified as short- sighted, if not seen as obscene [4]. Robots for example might save time when performing a specific task in a production line. But what isn't currently taken into account fully is what extent this object is "enriched" with knowledge and expertise to develop it, and how many resources and machines had to be used to create it. How much energy is needed to reshape the robot's material finally into another object is also not acknowledged. The concept of un-reflected material greed and accumulation redounds very much upon the *Baby Boomers* of the 1970ies, which was mainly characterised by self-absorption and the following *Generation Me* by its

material greed in the 1980ies [5]. These trodden paths have subliminally conditioned us and looking back, it is sometimes hard to understand this "devil-may-care"-attitude. Even more shocking; industry nowadays still adheres to the 150-year-old concept of planned obsolescence [6].

OUTDATED VIEW ON RECYCLING

Recycling itself has become a concept that needs reconsideration. We apply our mechanical understanding to recycling methods, like shredding, smashing and melting, which again, uses up energy instead of generating and providing it. Just so, that no innovation or interrogation has to go into the origin of the resource itself! In fact recycling often uses up more energy than producing virgin plastics and therefore becomes redundant [7]. Seen as starting point for behavioural change in society it might be great way to create awareness in people, but the fundamental mistake lies in the method itself: while tearing the object somehow apart, its value gets mechanically even more enriched, whereas its embedded energy should instead be extracted. This activity should be performed as actual live sign of a creature or offered as a food- source, like microbes nourishing themselves on rotten matter, rather an artificial performance to translate matter into a different shape.

The manufacturing side of society needs to activate its own responsibility. Investing efforts to work with the powerful forces of nature instead of artificially creating cycles, that aren't closed, need to be a main agenda within our lifetime. This could shift the current negative perception of genetic engineering that we have inherited. Properly applied, these methods could actually help our human race to create a symbiotic relationship with the nature in which we live. This is where the engineer, the thinkers, and the makers of society have to intervene. Since human mankind evolved, those were the driving forces – only a paradigm shift on the agenda seems overdue.

THE ROLE OF CRAFTSMANSHIP

Also the culture of making and crafting objects has radically shifted only in the last century. Craftsmen in previous centuries mostly had high degrees of both practical and theoretical knowledge of their trade.

I'm proposing to take a look backwards, to gain insight before then speculating on potential future applications: If we believe that a structural re-thinking of our material culture is necessary, we rely on the mastery and specialism that is going to be key to the future of work! Much can be learned by the experiences of craftsmanship.

Craft based work requires skilled repetition of actions, and with each repetition the content changes and the skill becomes more refined. Richard Sennett describes this as *circularity,* as a virtue of repeated practice, leading to embodied knowledge [8]. Through these repetitions the tacit knowledge of unspoken words are absorbed. Craftsmanship also differs from modern perception in terms of how we split or unify our personal life and work. In the Middle Ages craftsmen slept, ate and raised children in the place in which they worked. Labour and life mixed face-to- face. The communal ritual of this hands-on transmission, or the knowledge capital, formed the craftsmen' economic power. One can only see such arrangements in alternative fringe communities or women who run little cottage industries. Private life and work are nowadays strongly held apart, and not always for the better.

But also personal reputation, trust in each other's ability and personal reward are considered the most important obligation of the craftsman. This is also reflected in the pride the guilds represent. One's prosperity directly depended on probity and establishing a *good name* of the quality goods they produce. This type of self-branding holds, beside the official duties, also a satisfying personal distinction, compared to many faceless jobs people do to earn a living.

CRAFTSMANSHIP AND BIOTECHNOLOGY

But which product or field would convince our overly satisfied and spoilt society to value slow manual work again? It becomes very obvious, that the idea of manufacturing banal goods that can be easy produced by any machine won't convince a broader mass to see the surplus value of this reconsideration. This is where biotechnology comes into play. We have currently an ever-ageing society with an immense scarcity of human organs and regenerative therapies. The biotechnology market's current value is around 28,3 billion Euro in Europe, with a constant growth rate of around 10%, 14,3 % in the US and 9,2 % in Asia [9]. We seem to shift from "hardware" to "wetware" – which could also indicate a shift towards Cronenbergian hybrid products - known from science-fiction films like *Existenz* [10].

Figure 1. Working in Cambridge Universities' laboratories of the Plant Sciences Department for iGEM.

Last summer I worked as Design Advisor for Cambridge Universities' iGEM team (International Genetically Engineered Machine Competition) [11]. Together we developed a project that extracted and extrapolated reflectin from squid - the protein that creates structural colour and the striking iridescence in squid's tissue.

Figure 2. The squid Loligo Vulgaris produces striking iridescence in its skin.

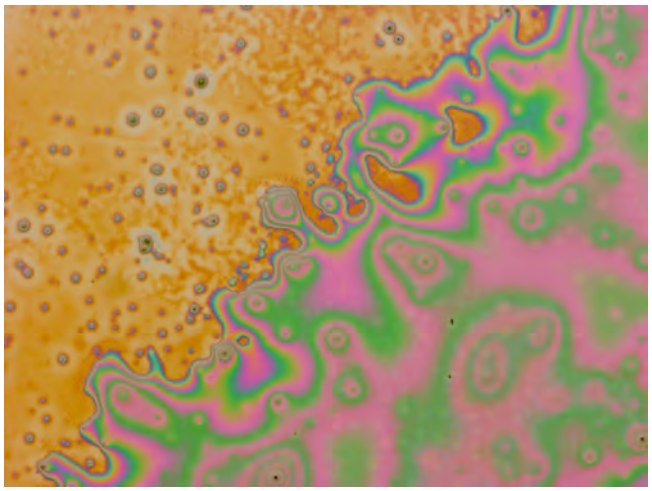

Figure 3. The developed thin films showcasing iridescence achieved by extracting reflectin from squid. The colour change is effected by humidity change in the air.

One potential future application could be a biodegradable computer screen, running with the full colour spectrum of iridescent colour instead just RGB. Fully developed this technology would reduce cost, improve usability and make use of biodegradable resources [12].

ADVANTAGES OF BIOTECHNOLOGICAL CRAFTING BY THE EXAMPLE OF ORGAN CRAFTING

But even more remarkable would be the slowness of manufacturing hybrid biological goods. Cell growth can be only optimised to a certain extent, but it does require a certain period of time, one can't bypass or speed up. This may sound limiting in the first place, but if we take into account how much work and negative consequences like pollution our current industry culture creates, it might weigh out the slow production in the first place several times over.

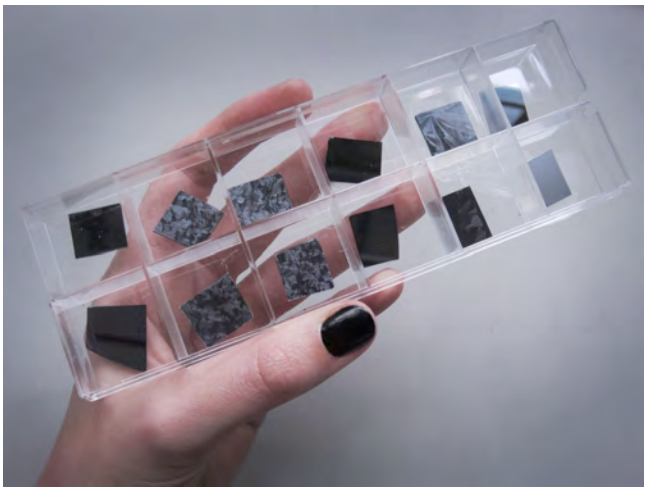

Figure 4. The final thin films.

With the project *Organ Crafting* I envisage genetically modified silkworms weaving collectively the scaffolds for human replacement hearts. Genetic engineering would in this case allow for alteration of the construction plan of silkworms, in order to spin their cocoons to suit our needs. This could potentially allow for one of the *greenest* production lines ever known. The worms only feed on white mulberry leaves (Morus Alba), which they require three times a day plus dedicated human labour. The silkworm has to be fed around four weeks before it starts spinning the silk for the following three-four days. What sounds like a rather long-winded production, saves effectively all time for the non-necessary recycling afterwards. Silk as material is currently on high demand – not only for the biomedical market, but also for fibre-optics, sensors and the IT-market. Its excellent material properties make it a high-tech material with very modest production effort and the usage of local resources. I mentioned the unification of life and work in the past lives of craftsmen. Sericulture could be promoted as main business, but also provide serious extra income as cottage industry.

The epicentre of the silkworm industry lies in China, Japan and India, and many attempts have tried to also bring it to Europe. Frederick the Great for example put serious effort into establishing sericulture in Europe in the 17th century to aim for cheaper production of luxurious garments. The mission failed entirely due to non-suitable climate conditions for the mulberry trees, resistance of the local winegrowers and diseases, which killed the silkworms and made the business not profitable anymore [13].

Observing these conditions that caused the failure of the silk industry, it becomes obvious that advances in genetic engineering could tackle and address these issues: Specific silkworm breeds are much more resistant nowadays and even allow to be fed on other plants than mulberry. The demand in biotechnology would open a new field for business and the modest effort in running sericulture would make natural resource-deprived areas like Europe an

interesting location. Locating the material delivery (silk) and the processing biotech-laboratories (tissue engineering) nearby could even improve the overall progress of the field and open up new collaborations.

WHY IS SERICULTURE STILL CONVINCING?

What I find particularly striking is that we have domesticated the silkworm for more than 5000 years, but up to now we still haven't found a technology that can mimic the specific properties of real silk. During my research at University College London, I found out that even the most complex machines for bio- spinning silk proteins don't master the quality achieved by a single worm [14]. The problem hereby is the fragile nature of protein, of which the silk mainly consists. The current approach to the machine-driven spinning is to fill large tanks with silk protein in order to quickly weave large (industrial) amounts of silk scaffolds. Large quantities of proteins however tend to agglutinate too readily in the tank before they are even spun into thread. It seems currently impossible to tackle this problem, without adding chemicals to the mixture, which lower as result the quality of the silk. Only the silkworm itself seems to have the ability to balance the exact right amount of body size (material) and its spinning nozzle. After finishing a cocoon, the *production nozzle* even turns into edible food – silkworm pupae is very commonly eaten in Asia and India. If not eaten, the pupae are finely ground down for usage in cosmetics. Only time, experience and mulberry leaves are required. Experienced people, who devote their labour to nourish the delicate insects and to turn the outputs into biodegradable objects, like human organs or even consumer electronics.

Currently, consumer products are built to only *appear* stabile and long lasting, whereas the quality is often so badly that it has to be chucked away shortly after the purchase without the option given to maintain and repair it. If the object should only convince at the moment of purchase, to then cheat the customer when using and leaving the disposal of it up to him as well. So, why do we not consider products from scratch biodegradable? Most products only last for a certain amount of time anyway – especially in the IT world. Perhaps products don't need to be made to appear as if they will last forever – everyone knows they won't. If we could utilise genetic engineering to grow silk scaffolds for objects, we wouldn't need to develop expensive machinery, to be party to certain elitist knowledge to engineer tools for building such machines, to dig for the steel, or to understand the logistics of materials, to turn them into fully functional machines and no electricity to run all of this.

With regards to cultivating human tissues, like organs, the laboratory personnel has to nourish, clean, and observe the matter meticulously to improve its growth. Many steps can be automated surely, but dealing and responding in an appropriate manner to unpredictable parameters - which matter biological origin requires - demands an experience as embodied in the craftsman. This cannot go unnoticed. I particularly like the idea of an *organ* craftsman, who devotes specialist knowledge and time to creating an individually tailored organ on demand. What is currently going unconsidered is the traumatic experiences people deal with, as when they are about to receive a donor heart, for example. This ordeal sometimes even induces a personality alteration, breaks up relationships or renders one alienated in the carrying of another person's heart. Surviving the intensive surgery very commonly causes a post-transplant-depression - an emotional dilemma such as guilt and the feelings of benefitting from another persons' death. Receiving a donor heart comes with the additional risk of immunosuppression – the rejection of the new organ [15]. In order to prevent this, strong medication has to be given to enable the healing of the organ, before the body can reject it. This draining therapy also keeps the patient in constant anxiety and increases the distressful experience of the treatment. There is also no such thing like a tangible preparation for receiving a donor heart, as the organ has to be transplanted in a very fast procedure within hours after the donor has passed away to keep the organ fresh. Once the ill organ is being replaced the patient awakes with the abstract – and painful - certainty of being partly someone else from now on.

Figure 5. The donor heart recipients visit the organ craftsmen to see the commissioned organ.
(Biophilia – Organ Crafting, Mixed Media, 2011)

Figure 6. The silkworms weave collectively the desired shape instead of their cocoons.
(Biophilia – Organ Crafting, Mixed Media, 2011)

In the scenario of *Organ Crafting* I envisage a completely different picture of how such a process could happen in the future. Patients with cardio-vascular diseases very commonly live in the knowledge that they need a replacement heart once it's diagnosed. This would allow for the organ craftsman to manufacture the silk scaffold individually for the patient – perhaps based on magnetic resonance imagery data (MRI). During the process of weaving the scaffold the patient could visit the craftsman to see his future neo- heart and build a relationship with the organ and its maker, in order to develop a positive attitude towards the upcoming surgery.

Experiencing as patient the time and effort that goes into the highly symbolic and personal organ of a neo- heart, would surely increase the feeling of appreciation and increase the esteem of the patient. Silk as scaffold material holds unique material properties of ideally degrading the scaffold at the same rate as growth of the new tissue in order to be integrated into the surrounding host tissue [16]. Once the silk scaffold is finished, the patient donors non-specific cells of his body to the biotech-laboratory, which reprograms the cells into induced pluripotent stem cells (IPSCs) [17]. This type of cell has in theory the same capacity of embryonic stem cells to transform in any desired shape and will deliver a nearly identical match to the donors' tissue and therefore avoid a rejection of the organ.

Figure 7. The silk scaffolds - waiting to be brought to life.
(Biophilia – Organ Crafting, Mixed Media, 2011)

But beside the excellent qualities of material and the potential of application, I find a particular beauty in the interaction of the craftsman and the patient. The patient feels appreciated and respected with his fears and the craftsman's work gets in return elevated to a higher level of meaning.

PERSONAL IMPACT OF A CRAFT- BASED WORK

The pleasure in making comes from innate necessary rhythms - often quite slow ones [18]. Doing a job properly takes the time it takes and much satisfaction lies in the activity if we do not rush. While working, we are submerged in the processes of thought, and our feelings are in progress: almost unaware, we apply our own standards of well-executed work to the larger ideals of "good" in general. I like to compare this *experience*, which is as English word quite fuzzy, with the German equivalent, being specified into *Erlebnis* and *Erfahrung*. *Erlebnis* represents an event or a relationship that makes an innermost emotion impress, whereas *Erfahrung* means an event, an action or a relationship that turns one outward and requires skill rather than sensitivity.

It is believed by some pragmatists, that if you stay solely in *Erfahrung* one might be trapped by means and end-thinking and acting and may succumb to the vice of instrumentalism. What is therefore needed is the constant inner motivator of *Erlebnis*, of "how it feels"! Taken this as a concept – what does it imply?

We would perhaps shift our focus from pure functionality of the production line to also appreciating value in mundane procedure, on form of action, on rituals – generally speaking on techniques of experience. These would guide us even in encounters that happen only once by furnishing an envelope of tacit knowledge for our actions.

CONCLUSION

I'm presenting the argument that craft of making physical things provides an insight into techniques of experiences, shaping our dealings, our attitude - if not respect for others. Both, the difficulties and the possibilities of making things well apply to making human relationships. In this case a manufacturing method, which allows for non-invasive production of goods could even question how we anchor ourselves in the world around us. The fusion of ancient techniques and high-tech sciences would not only address practical ecological and economic issues, but could also provide alternative consideration to what future craftsmanship could mean to us.

I see potential in applying and evolving the principles of Slow Technology to biotechnological craft, in order to enrich our community life, as well as enriching work life as a life-long learning experience, one learnt from craftsmen. Biotechnological crafting could provide an alternative: biodegradable products that would be appreciated by the growing numbers of eco-aware customers and perhaps induce a paradigm- shift towards genetic engineering.

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