AFFORDABLE AND ADJUSTABLE PROSTHESES CREATED IN FABLABS

ALEX SCHAUB

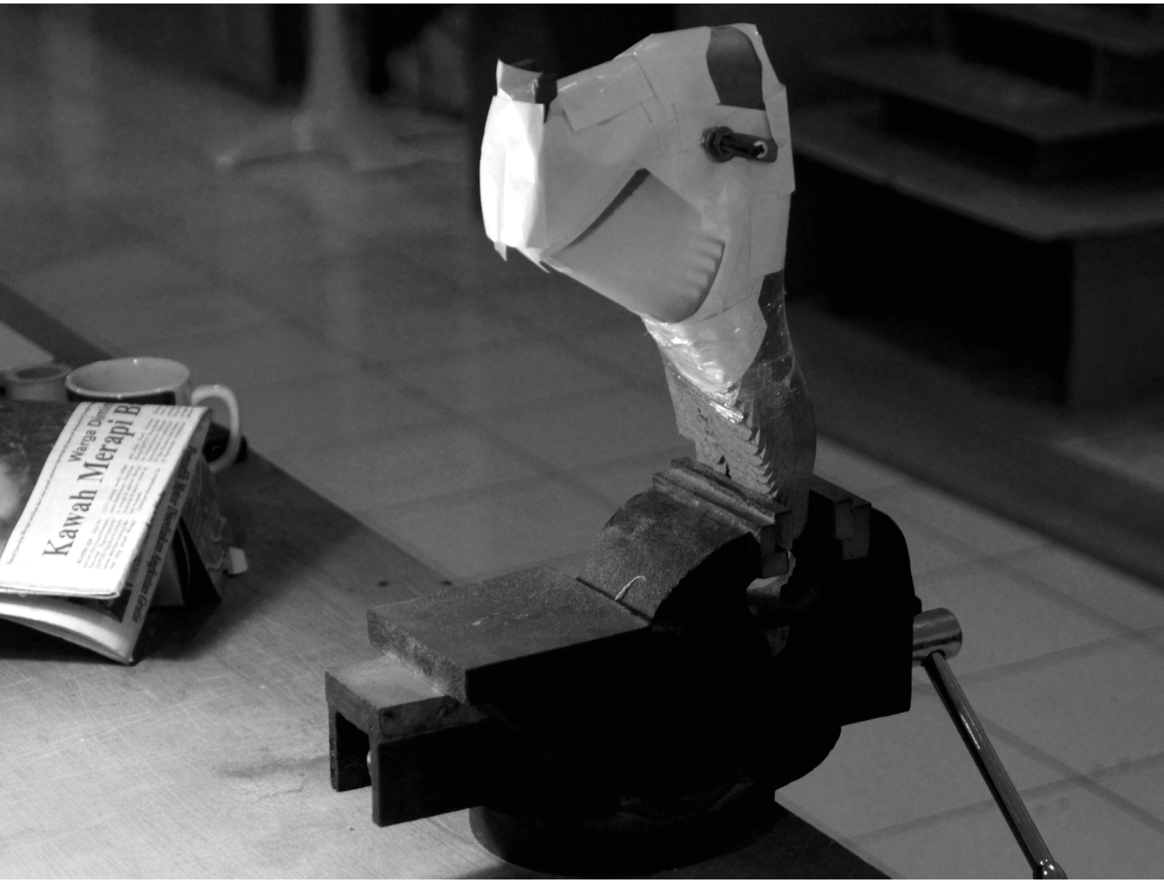

Figure 1: Prosthesis production (Source: Photography by Alex Cuff).

1. Introduction

The bi-annual International Trade Show for Prosthetics in Leipzig, Germany, shows all the high-tech breakthroughs and innovations in the field of prosthetics at the highest international level. However, for most people in developing countries in need of a prosthesis, these technologies are out of their reach as they are unaffordable. Yet, in one corner of the tradeshow, there are a couple of square meters dedicated to low cost prosthetics. The Red Cross, for example, has an affordable prosthesis, which is even sustainable. One of the questions raised by Waag Society (an Institute for Art, Science and Technology) in Amsterdam, The Netherlands, and The House of Natural Fiber's (HONF) FabLab in Yogyakarta, Indonesia, is, if it is possible to produce a sustainable, high-quality, low-cost below-knee prosthesis, which could be produced in local FabLabs, using local materials. This article describes the efforts of the $50 Prosthesis Project, a collaboration between HONF and Waag Society aiming at creating affordable and self-adjustable prostheses for people in Indonesia.

The House of Natural Fiber's FabLab has initiated a number of projects in the surrounding area, ranging from arts and design to education and public services. In line with its consistent focus on interactivity between people and environments, HONF selects and structures its projects based on the needs of local communities. One of these projects includes research on production and fabrication processes in relation to such fields as robotics, Open Source, and sciences (e.g., microbiology). One of the partner organizations that benefits from the support provided by HONF is Yakkum, a rehabilitation center for disabled people. HONF has been collaborating with Yakkum for almost nine years, working as a non-official mediator and facilitator through workshops in the field of arts and empowerment. The collaboration with Yakkum confronted HONF with its biggest challenge in the context of fabrication processes. Yakkum also produces prosthetics and orthotics for people with physical disabilities, particularly in Yogyakarta and other urban areas in Indonesia. However, these medical aids are expensive to produce, and the making takes much time, seeing as it takes two weeks to finish just one prosthesis. The situation is particularly problematic since there are many patients who urgently need prostheses, and most of them come from poor families. The aim of the $50 Prosthesis Project is to enable Yakkum to provide prostheses for ten people a day using FabLab technology.

2. How to Build Prostheses?

The development of a high-quality, low-cost prosthesis, which is self-adjustable enhances the quality of life of the user, particularly in combination with the user's possibilities of adjusting the prosthesis him or herself. For the design process the knowledge of a user is implemented in an iterative process, and the workplaces of FabLabs are furthermore linked with experts, hence knowledge can be exchanged through the already existing communication channels (a videoconferencing system has been set up among the cooperating FabLabs).

2.1 Challenges in Building Prostheses

The focus of the developing process lies on:

- Lowering the costs of the prosthesis (sustainable, local materials);
- Exchanging knowledge on the process of prosthesis production;
- Applying the user's expertise and involving them in the process of producing affordable health solutions;
- Combining the expertise of both the 'real' professionals and the 'user professionals' in developing an adjustable prosthesis that improves the user's quality of life.

2.2 History of the $50 Prosthesis Project

The first step in this collaborative process took place in May 2009, when the Waag Society's FabLab of Amsterdam invited HONF to an introductory prosthetics workshop for an initial exchange of experiences between users and designers. The workshop covered methods, techniques and materials and included expert input from Hugh Herr, the director of the Biomechatronics Research Group at Massachusetts Institute of Technology (MIT), and Marcel Conradi, the director of the De Hoogstraat Rehabilitation Centre in Utrecht. In addition Appie Rietveld, initiator of Korter maar Krachtig, a Dutch support and advocacy group, provided an end user evaluation for people dealing with limb loss.

A second prosthetics workshop in January 2010 aimed to define design parameters for adjustability, to devise inexpensive, efficient methods for production, and to explore the use of local materials – for instance, using local bamboo instead of aluminum reduces production costs considerably. A very useful insight emerged, when we discovered that the patent of the 'pyramid adapter', a crucial part of the prosthesis, was expired, which allowed the collaborating partners to re-engineer it. The next step was to test a first bamboo prototype and to make it adjustable. Most prosthesis users currently depend on orthopedists for every minor adjustment of their prosthesis, but that could theoretically be avoided. Many users do not realize that they already have a lot of first-hand knowledge about their own prosthesis, since they wear them 24/7; they are the experts at their own prosthetics use. Children generally need to have their prosthetic legs recalibrated by a doctor every six months. In Indonesia, this costs a lot of time and money. An adjustable leg would enable end users to adjust their prosthetic legs themselves by feeling and experiencing the fit, measuring the prosthesis and adapting it.

Walking on different surfaces also requires adaptation of the leg. The roll-off curve of a foot changes drastically when walking on different surfaces. The majority of prostheses on the market are designed for just one standard surface. An adjustable prosthesis would enable users to manage aspects like the roll-off curve, the angle of the foot or the height of the prosthesis themselves. In Indonesia, prosthesis alignment is mainly done manually. To facilitate the process, the collaboration team started to develop tools, such as a cheap alignment laser device and a portable 3D scanner. As DIY kits, these tools could improve accuracy while remaining affordable and accessible. Besides using digital fabrication resources, the team embraced open innovation principles, like pooling knowledge from the expert users in Yakkum, the designers from HONF and FabLab Amsterdam, academic advisors such as Prof. Dr. Bert Otten (Center for Human Movement Sciences, NeuroMechanics and Prosthetics, University of Groningen) and specialized manufacturers like Orthopedietechniek De Hoogstraat in Utrecht. Input from all the parties was used in the process of developing and designing the adjustable leg.

The concrete results of the $50 Prosthesis Project so far also include key design insights: For instance, adjustability allows end users to take a crucial step towards independence, and the visual design of the prosthesis is important to end users. In addition, knowledge transfer during production is important for empowerment and self-reliance. In terms of production, the team gathered knowledge on how to use thermoforming to produce quality limb sockets quickly.

2.3 Future of the $50 Prosthesis Project

The next steps address specific, tangible end user needs and preferences. What do users need in order to adjust the prosthesis effectively? How would they like the design to look and feel? The aim is to develop a process or method for design based on the parameters defined in consultation with 'expert users': adjustability, open innovation and digital fabrication. To this end, a FabLab is set up in Yogyakarta with a special prosthetics section. However, it is a challenge to set up such an entity in a developing country and to make sure it is sustainable. After the pilot phase is over, the aim is to have a business plan to ensure that the FabLab could work as an independent digital fabrication workshop. The work on the $50 Prosthesis Project will hopefully continue after the end of the pilot phase.

The ambitions are to have a FabLab hub on prostheses, where research and practice are united. An online community was created (www.lowcostprosthesis.org), where experiences can be exchanged and case studies can be gathered so as to minimize the chance of reinventing the wheel. In the future, we plan to research options for using intelligent materials to enhance the experience and effectiveness for the end user. Another goal is to explore the use of embodied cognition. Embodied cognition means that aspects of the body shape aspects of cognition. Bert Otten expects the process of prosthetic design to be guided by the team's increased insight into the development of embodied cognition of physically challenged people as they learn to walk with the leg prosthesis. The physically challenged people's improved sense of dynamic balance can be observed best from the way they move and how they intuitively adjust their prosthesis. Consequently, no technical insight or expertise should be needed to adjust a prosthesis optimally, as long as the design is based on embodied cognition. This way of implicit learning is crucial. Learning to walk with a prosthesis is a sensitive process. Showing the user a video of his or her best performance is more effective than giving orthopedic advices or showing figures.

Recently, in the summer of 2012, we have been experimenting with composites containing natural fibers and Polyurethane plastics. With very fine pineapple tree fibers combined with a PU rubber compound, a surprisingly strong stomp socket could be completed (see Figures 2 and 3). The resistance and durability has yet to be thoroughly tested. In Indonesia crafters are prototyping sockets using the

Figure 2: Pineapple socket (Source: Photography by Mickael Boulay).
Figure 3: Vessels (Source: Photography by Alex Schaub).

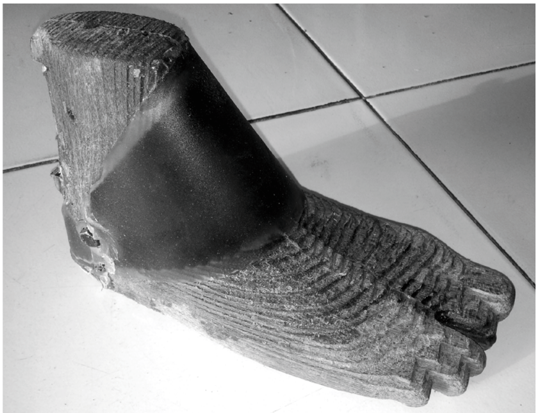

Figure 4: Wedge foot sketch (Source: Illustration by Jens Dyvik)
Figure 5: Foot prototype (Source: Photography by Alex Schaub).

traditional craft of bamboo coiling. Designer Mickael Boulay is currently prototyping an adapter that intuitively allows the user to adjust his or her feet and knee angle to his or her needs.

Another prototype we are working on is a new foot design. 3D milled wooden parts are combined with Polyurethane rubber to make a flexible, yet adjustable foot (see Figures 4 & 5). A second foot design approach is based on a molding and casting technique. Negative molds are casted on 3D milled wooden foot positive molds. Then the negative molds could probably be stuffed with a mixture of natural fiber and ideally natural rubber.

Further investigation goes into the bio data of the natural fiber itself. One of the most explosive questions we are researching at the moment is called, is it possible to find some oils within the biological structure that can be used as a binder for new resin types?

3. Conclusion

This article described why there is a need of self-adjustable, low-cost prostheses. And how Waag Society's FabLab Amsterdam and The House of Natural Fiber's FabLab Yogyakarta collaborate using open innovation system. Furthermore, it explained the challenges and planned future developments for improving the prostheses (development). All of the described prostheses' designs are based on locally available materials for low or almost no cost. The goal is to increase physically challenged peoples' awareness of their own prostheses, what will improve their daily experiences. Controlling their own prostheses will not be dependent on expert knowledge, but will be based on the physically challenged people's experiences and their empowerment. We believe this will have a big impact on society – everywhere.