The development and role of personal manufacturing. Case study: Open Knitting.

Varvara Guljajeva, Mar Canet Sola

Abstract: The paper argues about the importance of textile manufacturing in the age of digital fabrication. Today, the tools of desktop fabrication have been developing rapidly, at the same time the first digital personal manufacturing tool for home-use that is an electronic knitting machine from 1976 has been forgotten.
The first part of article aims to bring forward changes in manufacturing industry starting from the Industrial Revolution up to the today's tendencies towards a one-person-industry. As well the phenomena of Fab Labs and open hardware are discussed, and the absents of textile fabrication underlined.

Through several case studies, examples, and detailed technical realization of an obsolete electronic knitting machine's modification, we aim to demonstrate the efficiency and future possibilities for applying a knitting machine in the field of personal manufacturing and desktop fabrication.

Keywords: digital fabrication; open hardware; personal manufacturing; textile fabrication.

Introduction

It is exciting how the model of manufacturing has been changing throughout the time. Obviously these changes has been economy-driven and as well *vice versa*. To tell more, the industry searches for a novel form of existence, when economical crisis hit.
Lets start from the Industrial Revolution period (1760 to 1850), which replaced manual, personal, and hand-control manufacturing with the numeric controlled machines. Consequently, the mass production of items appeared with this paradigm along. The manufacturing model of Henry Ford is a famous one for describing the age of industrial mass production. During the Fordism period production was creating demand. It means, the industries were producing as much as they could and had big storehouses because they were able to sell all manufactured products.
When this model was not sustainable any longer, Post-Fordism, known as well as Flexibilism, appeared. This manufacturing strategy encouraged to produce on demand. In other words, this economic model does not have large stocks as the previous one, and the products are produced if there is a need.
Current economical crisis have demonstrated the failure of Post-Fordism. To be more specific, the consuming culture is in crisis because people prefer to create and produce themselves rather than generate desires that are then produced by someone else and not exactly according to the desire. Hence, the society is shifting towards personal and custom manufacturing that is strongly supported by the information age. In the words of Neil Gershenfeld the founder of Fab Labs' model: “the real impact of digital communications and computation came in giving ordinary people control over the information in their lives; digital fabrication will likewise give individuals control over their physical world by allowing them to personally program its construction.” (Gershenfeld, 2007, p.241).

Lets get physical!?

We agree with Gershenfeld that individuals are excited to have a control over their physical worlds. Moreover, Lipson and Kurman write about the phenomena of a factory at home and

one-person-industry, which is not a vision or future prediction but presence already. There are a number of proofs for such a claim, but the most vital ones are open source hardware and software, and an active community around the raising paradigm. For example, 3D printers that were for industrial use and not affordable for individuals, can be now, in 2012, purchased for 1000 euros. Obviously, an industrial machine has better specifications, but still a self-assembled RepRap can be applied for prototyping, that is what an industrial 3D printer actually used for, including a small-scale production and even self-replication. Indeed, the term 'self-replication' is very new and intriguing in the field of manufacturing. But what is more important, the price of the machine is dropping and features improving because the machine is a open hardware. There are lots of 3D printers that are open source and through the innovation and contribution of the whole community the development curve is extremely rapid.
Concerning further reasons for the advent of digital fabrication, open design and as well software play an extremely important role. Thanks to the database of designs that are available online, like Thingiverse.com, one can find a huge number of 3D models and as well share their own designs freely. Hence, even non-experts are able to start experimenting and producing desired items. As well open code is crucial for understanding and improving the performance of digital fabrication machines.

Fab Labs – the gatekeepers

Fab Lab started in the Center for Bits and Atoms at MIT in 2005 with an idea to provide students with facilities for realising their ideas in a physical form. Today, the idea of these labs has transformed into a growing international network of Fab Labs: in 2011 were over 50 labs in 16 countries. This fact can be seen as an indication for a great interest towards digital fabrication.
The machinery list of Fab Labs communicates their main focus, which lies on 3D printing, laser-cutting, CNC machine, and the production of PCBs. It constitutes that the whole point of digital fabrication is about manufacturing hard-surface objects. In our point of view, this approach is too limited and fabrication of textile has been totally overlooked. True, some labs do have sewing and embroidery machines but they are rarely used. Moreover, these machines are not open source.
Before concentrating on the personal manufacturing of garments, we would like to discuss the role of Fab Labs in the field of digital fabrication and its rising importance business- and community-wise. We believe that the network of the labs has spread the word and theory of digital fabrication significantly. Especially because the most of Fab Labs are connected to universities, and thus, are use to and need to produce as well theoretical knowledge. At the same time, behind the nice story of personal manufacturing is very limited access to the Fab Labs. The limitations are caused by price, location, opening hours, and as well the curatorial program that has been occurring in certain labs. However, the idea of desktop fabrication has still ground thanks to the movement of open source manufacturing that enables individuals and/or collectives to purchase inexpensive machines or build them from scratch. Hence, we see a parallel movements to the Fab Labs that is about building a factory at home, establishing an one-person-industry, and as well making co-owned labs in garages or studios. All this is possible because of affordable price of basic equipment that satisfies the needs of makers. For example, open source 3D printers and CNC machines are accurate enough and as well scale is acceptable.

Knitbot to every lab!

The number of start-ups and small-scale companies applying digital fabrication devices as their core business idea is increasing. Makers, designers and artists, who have invested in buying a 3D printer and/or laser cutter, in addition to their work are printing and/or laser cutting designs for others, too. Now people as well replicate machines and sell, which all in all pays back the investment soon.

We believe that all these results could be augmented if textile fabrication had been added as well. Individuals, who are producing stuff and making their living from digital fabrication practice could have more possibilities for creation and as well business. And what is more important, the bigger amount of people could be involved, especially the ones, who are skilled in handcrafts, like knitting and sewing. Hence, introducing overlooked manufacturing field will certainly bring innovation, and novel business and collaboration models.

The history of knitting

Since our case study is based on an electronic knitting machine, we will focus on knitting and the history of this craft in the field of textile manufacturing.
People know how to knit since ages. The origins of this craft go back to 400-500 BC. The first stocking frame knitting machine was invented by William Lee in 1589 (fig.1). The first machine was destroyed by knitters because they were afraid of losing their jobs. A circular knitting machine was found in the late 19th century and gained its popularity during the First and Second World War because of the need of woollen socks for soldiers.

Figure 1. The First stocking frame knitting machine by William Lee in 1589[1].

Concerning the first machine for home-use, it was a flat hand-powered knitting device by Cottage Industry back in 1890. This machine was as well used by small-size factories at that time. However, the real boom of home-use knitting machines started with the edition by

1 Image from: http://larkabout.wordpress.com/2009/12/11/the-hosiery-factory/

Brother that introduced its first non punch-card machine Brother KH500 in 1955. During the period of 40 years Brother has released a big number of knitting machine models, which all have different features and improvements. In 1971 was developed the first punch-card knitting machine KH800.
In 1976 came out KH910 – it was the first electronic knitting machine made for home-use. This machine was followed by other models, which had improved features for creating own patterns either via drawing on a mylar paper and then scanning it, via manual input-mode, via a floppy drive, or via a PPD device that allowed pattern making on a TV screen. Most of Brother electronic knitting machines allow 200-stitches-wide pattern upload, have about 600 preprogrammed patterns and multiple modes for uploading self-made patterns. At this point we can make an important conclusion: an electronic knitting machine (fig.2) is the first digital personal manufacturing device at home.

Figure 2. Brother KH940 electronic knitting machine

In 1996, after the release of KH970, Brother had stopped the production of knitting machines. Nevertheless, Brother knitting machines continue to be the most common ones that people have at home. There are a considerable market for old Brother machines and price is increasing because of the demand. Even more interesting, people resell old floppy drives with self-made patterns on them (see eBay). Of course, there are other producers of knitting machines, like Passap, Toyota, and Silver/Reed, which are slightly more expensive, and hence, less popular.
Concerning knitting patterns in general, they are the first example for open design ever. Makers use to share and exchange their patterns since ages, even before the first knitting machines.
It should be mentioned that knitting has been not always popular, in the 80s there was a sudden decline of this craft, because of mass production of clothing and its inexpensive price. And what was more crucial, the community of knitters was shrinking. Even the majority of schools took out knitting from their education program.
However, with the appearance of Internet the situation had changed. The new communication and information medium enabled sharing, learning, and communication. For example, in 1998 started KnitNet, the first online knitting magazine. As well the raise of blogging culture and portals has engaged a huge number of people. And we should not forget video tutorials on Youtube that are incredible learning support. For example, we have learned how to use and knit on a knitting machine by following youtube tutorials. According to Chris Anderson, one of the curators of TED Conference, our brain is wired to decode the video better than text. Hence, video is more powerful medium than print. Moreover crow, desire and light are the

keywords that accelerate innovation. It means people not only learn from each other through online means but as well generate innovation.
To point out some figures concerning the growing interest towards knitting, Guardians writes following:

> But despite this decade-long reign over the lifestyle pages, the last 12 months have been particularly good for knitting. Peter Fitzgerald, a retail director at Google UK, says that while online searches for knitting-related terms have grown steadily since 2004, the growth this year has been really noticeable. "Our data shows that searches for knitting have increased over 150% just this year," he says. The term "knitting for beginners" has increased by 250% (Lewis, 2011).

Case study: reverse engineering of electronic knitting machine

Until recently an obsolete electronic knitting machine were missing up-to-date pattern-uploading method. Why to discard a device, if only a certain function requires improvement? In the case of knitting machine, the technique of knitting is not going to change. An improvement needs only the communication between a machine and computer. Accordingly, we are going to elaborate on the process of reverse engineering a knitting machine and its future possibilities.
The first known hack of an electronic knitting machine was introduced by Becky Stern from MAKE magazine. With the help of Steve Conklin, who has developed floppy emulation script in Python for uploading a pattern, she and her collaborators realised and documented the modification.
On Ladyada's site has been posted as well a detailed tutorial how to emulate floppy disk and upload pattern from a computer to a knitting machine. Unfortunately, the project has a number of significant drawbacks. First, the hack works only on Brother KH930 machine. It means, other machines are not supported, since each model has a different memory format. Furthermore, KH930 device has much smaller memory than other models that makes very uncomfortable to knit large-scale patterns. Second, the hack is really for experts. One needs to install Python programming environment and a number of libraries, which are not easy tasks, especially on Mac computer. In short, only the code without user interface is provided, which is too complicated for normal users.
The second approach is the physical simulation of knitting machine's keypad. Travis Goodspeed and Fabienne Serriere have figured out all connections of knitting machine's keys on the circuit and mapped to Arduino pins (fig.3). Hence, one is able to press all buttons of a machine without touching any, but programming Arduino to do so. Since this hack was realised during a weekend-long workshop at Mediamatic in Amsterdam, achieved automatisation was very rough. It means, Arduino code does not do pattern-uploading, but just presses right code on a knitting machine for starting to upload a pattern. The upload itself was done via floppy emulation using Python script by Steve Conklin. It constitutes, this project is as well bounded to a single model that is KH930.

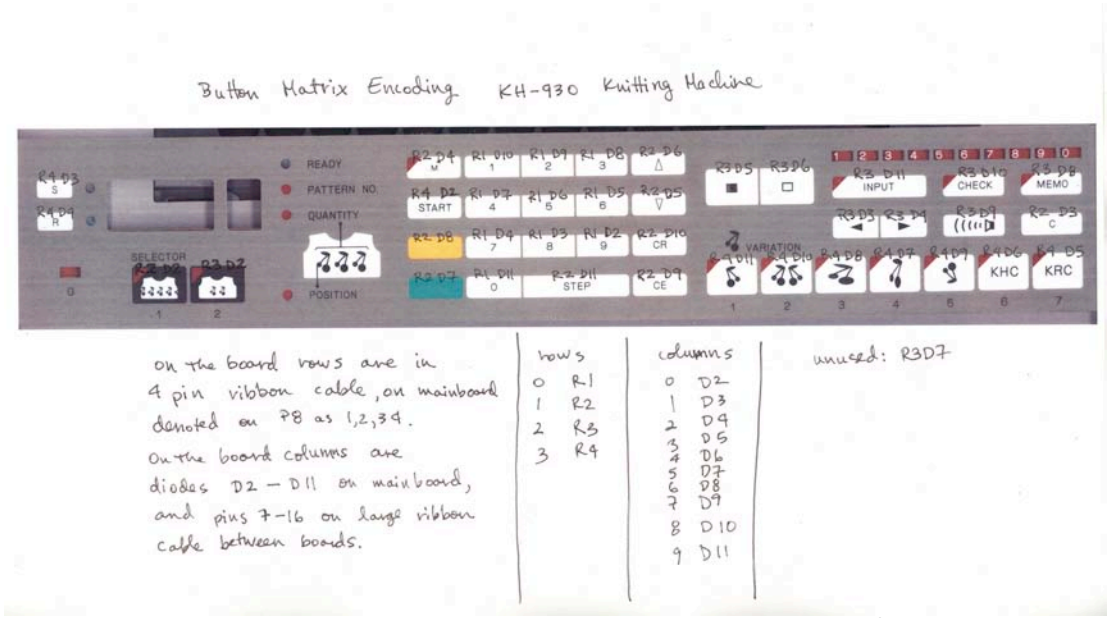

Figure 3. The mapping of knitting machine's keypad[2].

For our art project called SPAMpoetry we were unlucky enough to get KH940 machine. It did not take us long to understand that all documented hacks of an electronic knitting machine are pretty much useless to us. The Python code did not work on the KH940 because of the different memory format. Hence, we gave a try to the physical hack that is automatisation of a knitting machine's keypad via Arduino. Fortunately, the position and electronic connections of keys occurred to be the same and we were able to press all keys of the knitting machine via Arduino. Hence, we could go ahead and make Arduino to upload patterns for us.
To be more specific on the technical part, Brother knitting machines KH930, KH940, KH965 and KH970 have an INPUT-mode, which allows a user to insert a pattern manually by specifying a number of stitches and rows, and a position of contrast yarn's stitchs in every row. It means, after inserting a size of pattern, one needs go through all rows from the first until the last one pressing BLACK-button for contrast yarn and WHITE one for default yarn (see fig.4 for pattern). Obviously inserting big patterns by hand is not a good idea.

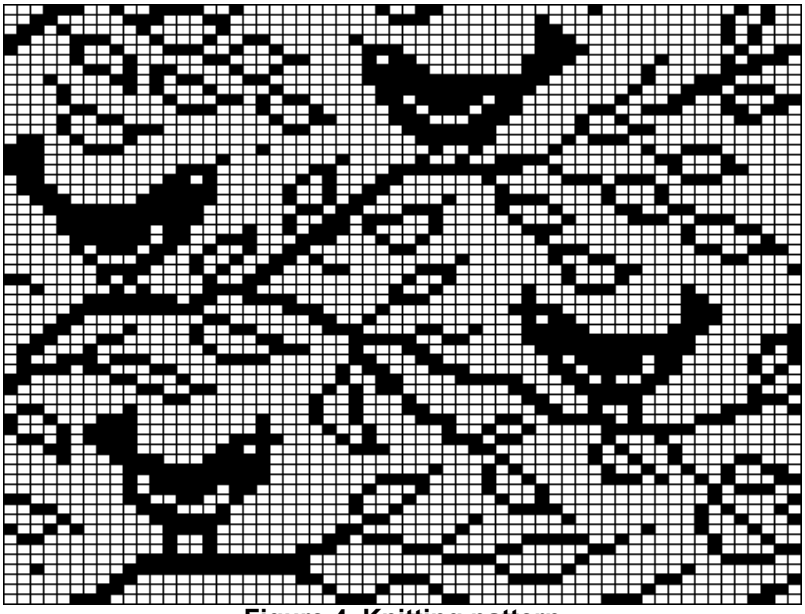

Figure 4. Knitting pattern

2 Image by Travis Goodspeed

Our approach consisted of two parts: breaking digital imagine into pixels in Processing and sending colour of each pixel starting from bottom left corner of image to Arduino. Arduino was then pressing right keys on the knitting machine accordingly.
The advantages of this solution were preciseness and compatibility with all models of Brother electronic knitting machines, which have an INPUT-mode. It means, ability to upload 5 times bigger patterns than KH930 allows, in case a different model from KH930 is used. The disadvantage was a slow speed. For example, the uploading of a pattern 180 stitches x 500 rows takes about 5 hours.
Because of the big minus that our automatisation via Arduino had, which is slowness of uploading process, we began to study file format of KH940 machine in order to be able to upload patterns via floppy emulation in few seconds. While in residency at STPLN in Malmö, Sweden, Davey Taylor was helping us to make sense of KH940 machine's file format. This significant knowledge enabled us to make a software program that uploads patterns to a knitting machine via floppy emulation. This improvement has a number of advantages, first our software supports several knitting machine models (KH930, KH940, KH950, KH965). Second, it runs in all operating systems and a user does not have to be a programming expert, since program is an executable file and has an interface for uploading patterns (see fig.5). Of course, the program is open source and all contributions are more than welcome. Third, pattern(s) get uploaded in few seconds. And finally, it is possible to insert multicolour-pattern.
The only disadvantage what we see, is the limitation of pattern-size that is bounded to the size of knitting machine's memory. However, we believe this issue is solvable (read next chapter for more details).
The last thing to point out concerning our recent modification, an electronic knitting machine has it's own 'brain' that is a computer inside, which makes sense of input codes. It constitutes, all the communication with the machine is done via key-code. For example, for erasing all user preferences and inputed patterns, one needs to insert 888 and then press STEP key. Basically, one has to speak knitting machine language for communicating with it. We did not want to learn all the commands by heart, and therefore, used Arduino for that purpose instead. It constitutes, we have combined the previous solution of keys' automatisation with the PatternUploader software. This approach gave us fast and reliable automatisation.

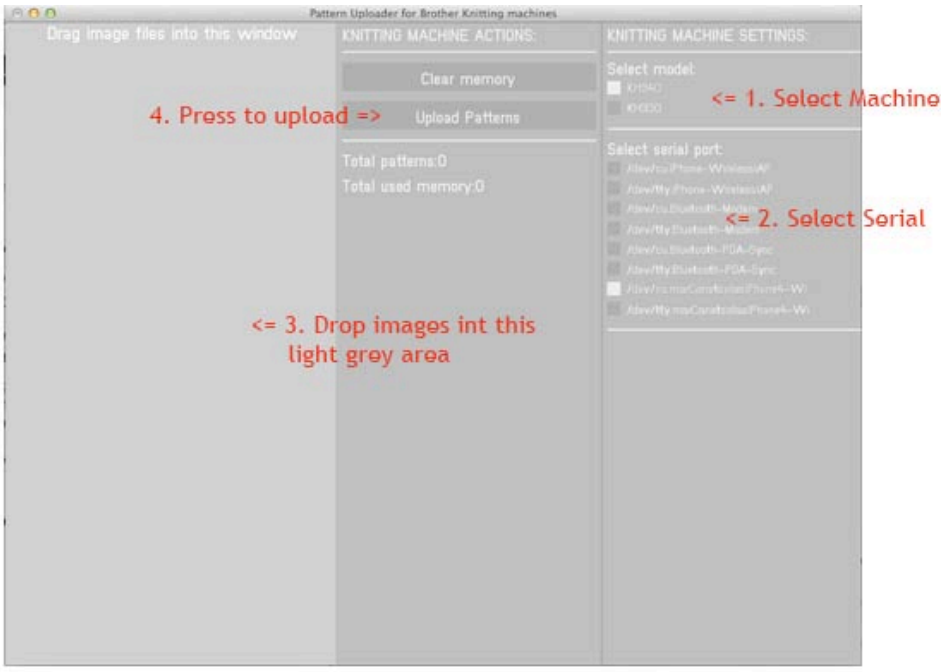

Figure 5. PatternUploader's user interface

In conclusion, it was a learning process for us to discover how an electronic knitting machine works and in which way it could be adapted to current needs. By studying work of others and the file format of machine, we have understood that the electronic knitting machines by Brother are primitive ones. In order to upload a pattern, one needs to dump all the memory of knitting machine and then upload it again. As well the simulation and automatisation of the knitting machine's keys enabled us to achieve a nice combination between floppy emulation via PatternUploader software and telling the machine to prepare for the upload.

Examples of artworks and knitted items using hacked knitting machines

In this section will be introduced couple of works realised with modified knitting machines as manufacturing devices.

Starting with our work, we have been producing a series of knitted sculptural works containing visual poetry from collected spam under the title SPAMpoetry. Concerning the concept, we are interested in bringing together digital culture and traditional handicraft. To be more specific, the idea is to experiment with the form and meaning of SPAM. We turn SPAM into a romantic, funny or even sarcastic poetry and present it in unusual tangible form as a knitted garment. We call the final result dysfunctional wearable, because it reminds a sweater but is not really a one. Like SPAM, our dysfunctional wearables do not have a purpose. Talking about the form of artworks, one is able to recognise sweater parts in unusual position and size (see fig.6 and fig.7).

Coming back to SPAM, it is generated automatically nowadays. Hence, we aim to apply the same technique for recycling it, generating poetry from SPAM algorithmically, converting into a pattern and uploading to the modified knitting machine. Of course, the process of knitting is done manually. Thus, we create a contrast between rapid and overwhelming digital world and slow, careful knitting process.

Figure 6. SPAMpoetry

Why we speak about SPAM? First, SPAM generation, distribution, and reception consume a significant amount of energy that is wasted basically. Hence, with our project we aim to draw attention to this fact and find a meaning and usage for SPAM.

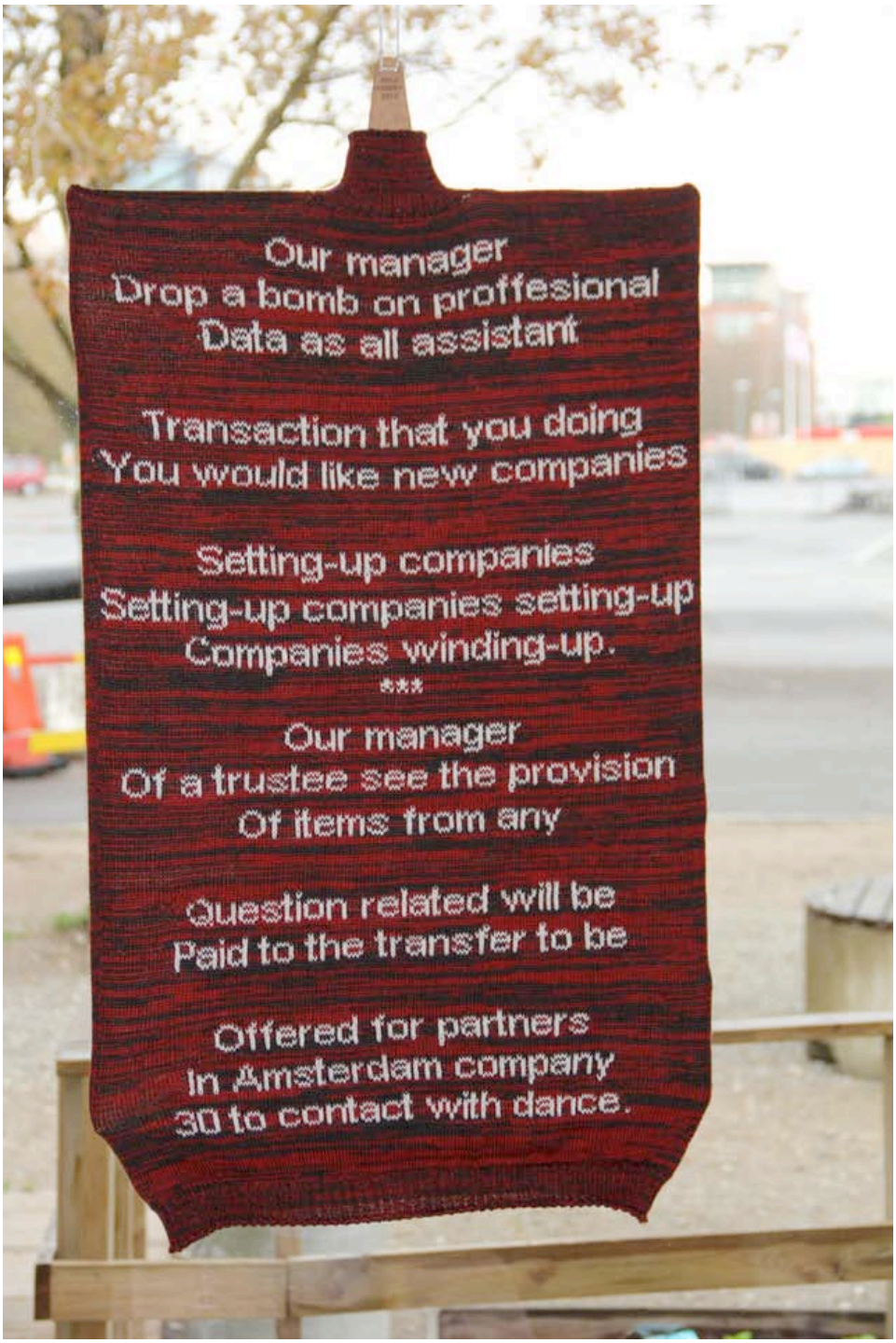

Figure 7. SPAMpoetry

Andrew Salomone is an artist from New York City, who has been producing a series of sweaters with realistic imagery (fig.8). He has collaborated with Becky Stern and lately has as well tried out ours and Davey Taylor's libraries for making multicolour-pattern knitted works.

Figure 8. Sweater made on a hacked knitting machine by Andrew Salomone

The practice of Fabienne Serriere is a good example for one-person-manufacturing. She has modified a knitting machine and now produces knitted items by applying parametric design approach and as well making her own patterns. On the image below are shown mate cosies by Fabienne (fig.9).

Figure 9. Mate cosies by Fabienne Serriere

These examples of reverse engineering a knitting device and applying for making knitted garments, are excellent proofs for possible adaptation of obsolete technology for present needs and appliance for textile manufacturing. And what is more important and interesting, often discontinued technology do not hold a pattern any longer, and thus, these devices can be produced as open source ones and can be improved according to the needs.

Future Plans

Continuing with the idea of open hardware, Brother knitting machines has been discontinued and Brother does not hold a pattern any longer. Hence, our aim is to remove 'the brain' of device and replace it with Arduino that will control the position of each needle. This improvement will allow an infinite row number of pattern and as well real-time pattern knitting. We believe the realisation of this idea will help to come up with the design for completely open source knitting machine, which can be made by laser-cutting and 3D printing its parts. Hence, a open source knitting machine will not depend on availability of old Brother electronic knitting machines.

Discussion

Drawing on the facts and research results presented above, we believe that textile fabrication has a huge potential in the age of digital fabrication and customisation. Moreover, knitting is a skill that humanity has been using for centuries. Hence, there are lots of experts, knowledge, learning and production material, tools, etc. On the contrary, the ability to 3D print or laser-cut have relatively few persons. It means, introducing knitting and textile fabrication in general to the desktop manufacturing communities and Fab Labs will bring more people and gender balance to these networks. Furthermore, the encounter of different skills and disciplines constitutes innovation most likely.

Clothing is relatively cheap and available nowadays, but as discussed before the model of manufacturing changes and individuals prefer to making instead of consuming. In order to keep up with the changes of manufacturing paradigm, several companies are searching for solutions to engage customers in the design process. For example, Nike has developed a web-platform Nike ID (nikeid.nike.com) that enables individuals to design and produce their personal shoes.

Moreover, in the time of current economical crisis people have more time than usual and prefer to spend it on making rather than on consuming and spending. Especially, clothing manufacturing is a common thing to do. Availability and recyclability of yarn are big advantages, too. And what is more important, taking into account the improvement of obsolete electronic knitting machine, it is easy to start-up a small-scale business or one-person factory for producing more than just for a personal use (see Fabienne's example above).

In the end, it is curious how an electronic knitting machine the first digital manufacturing tool at home has been forgotten by digital fabrication labs and open hardware developers. Therefore, we are sure in the importance of our research project and contribution to the field of personal manufacturing.

And finally, in our point of view it is impossible to talk about the shift of production paradigm by observing and describing the phenomenon of Fab Labs and novel open source machines that are able to produce hard-surface items mainly. At the same time, excluding all other areas of manufacturing.

To sum up, since knitting is well-known craft and there are lots of experts, it is a shame to run after new technology and forget good old skills. On the contrary, innovation should take advantage of existing knowledge.

Conclusion

The field of desktop manufacturing is gaining importance. The numbers of Fab Labs, persons possessing digital fabrication tools, and open hardware are increasing. However, all this

innovation is around certain fields, mainly laser cutting and 3D printing. At the same time textile fabrication has been overlooked.
We have used case studies for demonstrating and introducing the successful application and modification of Brother electronic knitting machines produced in late 1980s, which are the first digital personal manufacturing tools for home-use, actually. Moreover, our future aim is to come up with an open source knitting machine in order to wide-spread knitted garment fabrication.
In the end, it is a shame to forget early fabrication methods, which can be adjusted for the digital age needs. As well re-application of obsolete media is an interesting and novel approach in the field of digital fabrication.
Knitting and textile fabrication in general have several important advantages: the skills are common and there are lots of experts around, the availability and recyclability of material, and involvement of more people.
To sum up our message, we believe that development of digital fabrication and its creative applications is not a solution for economical crisis, but can be a great contributor towards innovative and creative communities, and thus, one of the activators of local economies. And therefore, it is vital the growth of makers' communities and inclusion of textile fabrication into the field of digital manufacturing.

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Author Notes

Varvara Guljajeva: artist / PhD candidate, Estonian Art Academy, Tallinn, Estonia.
Email: varvarag@gmail.com
Mar Canet Sola: artist / Master candidate, Interface Cultures in the Art and Design University of Linz, Linz, Austria.
Email: mar.canet@gmail.com