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研究成果報告書

Applying Digital Origami Patterns and Customization Service for Social Fabrication of Origami Clothing.

所属：政策・メディア研究科，XD Program 博士後期

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Abstract

Considered the production and wash of daily clothing consumes mass water and generates pollution by using chemical detergent, this project is inspired by Origami art to produce daily clothing by parametric Origami pattern, recyclable paper materials and open fabrication equipment.

If origami pattern can endow the critical flexibility to sheet material as fabric by the incision process with the laser cutter, it's possible to make alternative clothes in this approach.

To archive the goal, the project includes several part: (1) Build the parametric models of practical Origami patterns (2) A service sequence of customization system (3) An open fabrication machine of modified laser cutter for origami folding. Several suggestions for further process are submitted in the conclusion.

1. Background

1.1. Sweat Factory of fabric industry

Several social and environmental issues about the clothing's production and usage are noticed and motivated this research. As well known, currently most fabric and ready-made clothing are made mainly by the developed countries of Asia, Latin America and East Europe. In the fabric industry, the issue of "Sweat Factory" has been discussed for decades.The labors earn very few income and work overtime, but the huge demand of clothing from global consumers still drive this situation and got it more worth.

The factories of shoe and fabric industry in developing countries.

1.2.Water Pollution by detergent

Maintaining a clothing for its duration in daily using consumes inestimable water and produce water pollution within detergent. The ignored cost of water and water purification usually exceeds the clothing itself and more than we can image. The using detergent is also leaked to many areas there doesn't exist water purification

equipment, and the polluted water leaks to the river, lake and ocean.

The water pollution by using detergent.

1.3. Excessive Consumption of clothes

Most clothing are abandoned before they are really unusable, due to people's excessive consumption and abandon on clothing for various reasons, such as fashion trend's promotion or concerning social impression. Unfortunately, the clothing are usually more durable than their owners thought. Every year, tons of recycled clothes are transported to developed countries for poor people, but they don't need so much. The people who reuses clothes don't care about fashion and keep using them for years. Washing, organizing and transporting these recycle clothes cost more than themselves. Besides, destroying clothing is another difficulty, because new material technology makes them to be produced by complex ingredient or unable to be recycled or decomposed.

Tons of recycled clothes are collected and transported to developed counties.

A child in Madagascar wears a recycled uniform from primary school of Taiwan,

2. Concept

Above issues inspired several thoughts about alternative and environmental clothing:

2.1. Alternative fabrication without relying on mass manufacturing of fabric industry.

Consumers can't choose the harmful material of clothing by manufactures. Unless the law requires, manufacturers decide the materials based on the consideration of clothing performance and appearance, not environmental consciousness. Consumers can't decide how much these labors make the product can earn from the job, so sweat

factories exists. There should be a different fabrication to free consumers from mass manufacturing, therefore, the new fabrication, such as the personal fabrication, open fabrication and social fabrication could be the options.

An irony poster for Nike's sweat shop on the adbuster.org.

A Woo Chair made by open source and CNC.

2.2. **Endow clothing the appropriate duration.** According above mentioned, most clothing are too durable than we need and also difficult to be totally decomposed. Cheap clothing with less duration should be considered, because they can be used until unusable. If people used to change style frequently, they don't need durable clothes.

2.3. **Disposable clothing.** Nowadays, maintaining a clothes during its duration generates mass polluted water with detergent, and become a significant load for water purification system of city. Besides, wash also causes the clothes damaged and aged, and accelerate its abandon before unusable. What if there is a kind of disposable clothes for daily using about one or two weeks and without washing?

2.4. **Only produce when demanded.** As other product, the ready-made clothes are produced by mass manufacturing and stored, delivered and display until be pursued. The process includes many cost. The ideal goal is producing clothes for people who really need, not pre-made product in low labor cost countries and then transported and promoted on the market. That can avoid excessive production and consumption, and clearly knows who required what.

3. Solution

Based on above thoughts, we submit a solution integrated several points to response these demands and become a service design could be available in other fabrication type.

3.1. **Distributed fabrication (resource) -** Due to the recent bloom of co-working space, maker space and Fablab everywhere, these spaces consists of a new type of fabrication resource among the city, we called it as distributed fabrication. Not like industrial manufacturing locate in developing countries far away the market, these fabrication resource exist in the city, and closer to the consumers. This new type of resource can satisfied the goal of " Only produce when requires" and replace the mass manufacturing and its sweat factory. People can access the space, necessary

The global Fablab map shows the rapid growth of Fablab in recent years.

The wood buttons made by laser cutter and MDF from Fablab Amsterdam.

equipments and service to customize their own clothes near their residence.

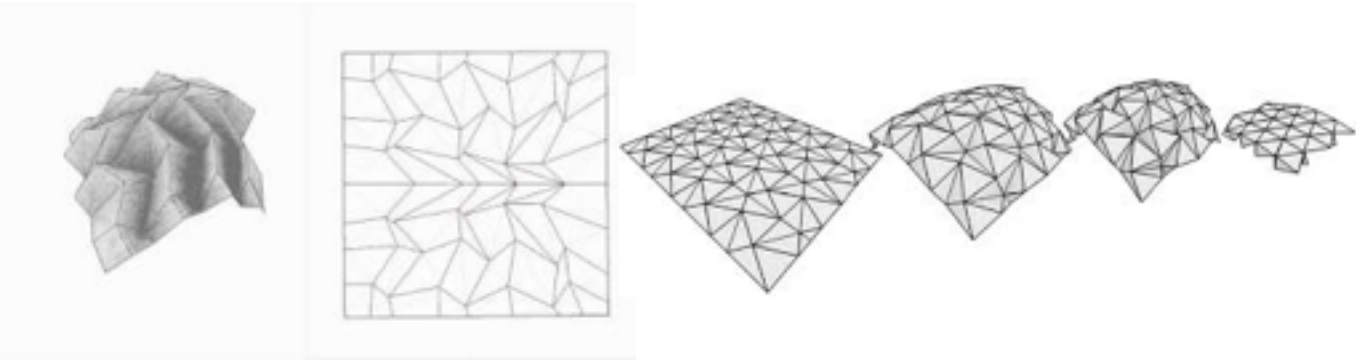
3.2. **Origami clothes (product):** Despite of fabric, after considered many possible materials, paper has the better performance on decomposition and suitable duration for an alternative clothes, and some hybrid paper material have water proof function as plastic. The question is how to make paper to be wearable as fabric? Our solution is applying the laser cutting and origami pattern on the paper and make it becomes flex as fabric. Although on the field of fashion design, the origami has bee applied on many works related to style design, but concrete product or manufacturing steps are not available in any access. We want to apply origami on daily clothes and match other purposes, not a wearable decoration. Our solution in this project should be an open source for people who interested in this alternative product and fabrication.

3.3. **Laser cutter (hardware):** Laser cutter has been equipped in most Fablabs as the standard machine for a long time, and also applied on origami creations as well as paper cutter in some study. Besides, laser cutter can work faster and produce large size material than the paper cutter. Somehow in this case, the laser cutter needs to be modified to proceed double-sides incision in following study, and the modification will be an open source for interested makers or Fablab staff.

Fashion design applied origami by Amila Hrustic.

Fashion design applied origami by Mercedes Arocena and Lucia Benitez in 2010.

3.4. **Parametric origami pattern system (software):** The role of parametric pattern system employed in this project is the pattern maker. Several useful origami patterns in our prior study will be parasitized and combined with clothes pattern acknowledge, and this parametric system can generate the origami pattern in one piece based on the 3D scanned data of customer's body. Another task of the system is generating the clothes pattern in one piece. Not like the traditional clothes pattern is consist of 4 or more pieces to form a cloth, the origami clothes in this project applies irregular origami pattern to endow different flexibility for shoulder and elbow. This advantage can simplify the after work. Besides, the system will be the critical part to accomplish the customization service, and also the idea for attracting customers, and apply the advantage of digital fabrication.



The online tool of freeform origami by Tomohiro Tachi, 2011.

4. Method:

The challenges of applying origami pattern on paper material for alternative clothes. There are two main tasks need to be solved here, include building the parametric origami pattern system and the numerous folding work for the origami clothes.

4.1. Material test: For making origami clothes, laser cutting is the incision processing within limited power laser energy to make mass incision on the material. Laser beam remove slight part from the material, so the paper needs to be a minimum thickness to absorb the laser energy. We tested several different paper for giving the reference of material selection, include tracing paper, vellum paper, Washi(和紙) and PP paper. The demonstrated gear in the test is the GCC LaserPro Spirit GLS, all regarded parameters of speed and rate are based on its setting. The below table shows the simplified result of best balance on laser's speed/power applied on those material and make them to be folded easier.

material / laser rate	90/10	90/20	90/25
Vellum paper 180p (模造紙)		O	
Washi (和紙) 70±5um	O		
PP paper 0.16-0.2mm			O
tracing paper 200p	O		

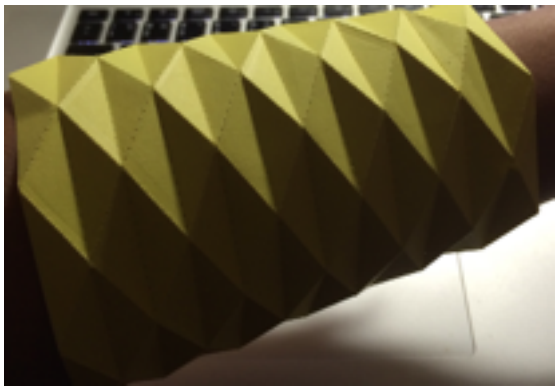
A table of material test result, the setting parameters of laser cutter for 4 kinds of paper.

Of course thicker paper offers wider range to test laser parameters, but most paper available in the art shop are too thin and burn by laser in the test. In the table, blank grid means the incision doesn't help folding or break after folded. Almost the balance of material volume and laser power exists for all material, if you can require thicker material. Some material may remain burn ash on the surface.

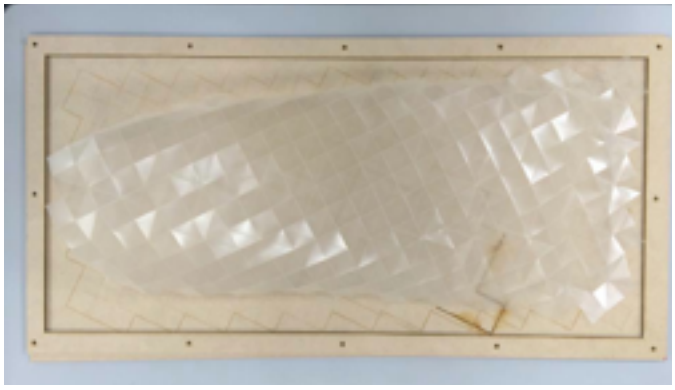
4.2. Dual incision:

Paper cutter and laser cutter are both applied on making origami in some study, but the common point is they only work on the only one side due to the design of machine. In the case of laser cutter, we will used dot cutting as below for folding both sides. But the result causes the paper is more difficult to be folded than hand cutting on double sides to apply the mountain and valley fold of traditional origami, and the folder gets confused to recognize folding directions. Although there is no such machine can carve on both sides, but we made a simple fixture for flipping material after carved on one side, and modify the pattern algorithm to generate the mirror pattern for second carving. We used the PP paper

to test it, and got good result to prove double-sides incision helps the fold work. Therefore, we planned a prototype of laser cutter equipped two sets of laser carriers and 2D movement system on both sides for dual incision. Not like other laser cutter, this prototype is placed vertically and may cause some danger when working, so a detailed process about how it work will be described in the next section.



The origami fold applied the dot cutting by laser cutter.



A piece of PP paper within dual incision of tessellation pattern and its fixture.

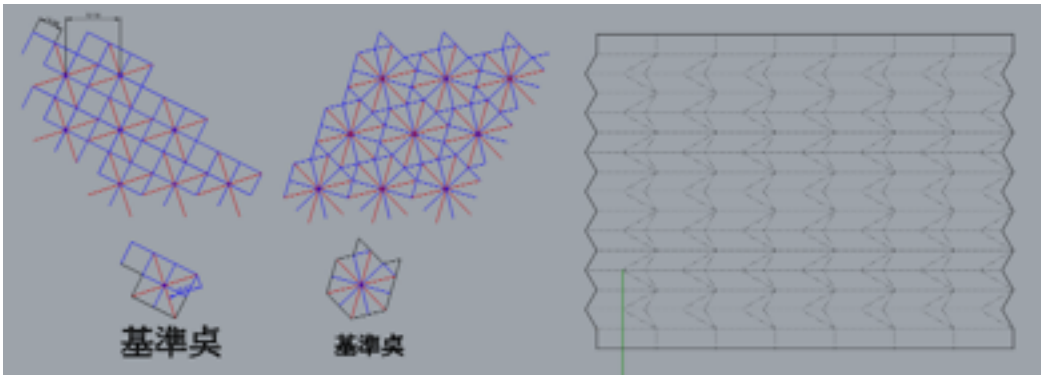
4.3. Lacer cutter for large area:

Another reason for the new laser cutter is the origami clothes requires material larger than the maximum working area (about 90cmx65cm) of biggest laser cutter. For example, the square tessellation origami pattern will shrink a flat sheet to the 1/2 of original area, so a flat paper for a origami jacket pattern will need a paper about 150x120cm. Besides, the paper carving only requires very low power of regular laser cutter and fixed focal distance, so the cost of prototype will be affordable for most Fablab or other open fabrication resource.

4.4. Origami pattern system:

4.4.1. The researches of origami in the recent decade have gained much progress and been applied on many domain, include architecture, engineering and design. The research result also provides very helpful context for this project. Although some patterns are digitized and could be simulated by the computer, but considered the authorization issue and availability, we have to build our own.

4.4.2. Three kinds of fold patterns are selected to apply on the origami jacket. 2 tessellation patters, include the square and triangle, will be applied on the trunk part, and bellows pattern is for the arm. The join area between 2 patterns is difficulty to connect perfectly, and some area has to be removed for after folded.



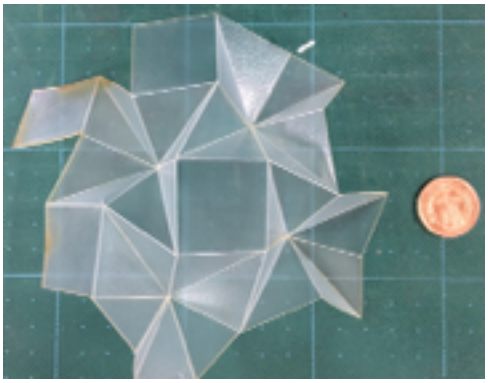
Two tessellation patters and Bellows pattern are parametrized in the pattern system, and can change the area and shape.

4.4.3. A parametric 3D upper body model is built and can vary based on a scanned body data. The system will apply the patterns on the 3D model, then unroll to a

flat piece and could be transferred to the vector file for laser cutter.

4.5. Folding work: Folding origami by hands is a time-consuming task, and also the main barrel for the practicability of origami clothes and service. Folding the whole piece origami clothes takes hours, so it's unacceptable as a part for customization service Therefore, we try to develop aid tools to simplified this task, such as 3D printed fold mold. For example, we printed a set of folding mold for square tessellation, because this part is the most difficult part to be folded. We used this molds to grip the origami part by part, and this tool accelerates the folding work, although it needs hands folding for the last step anyway. Unfortunately, the tool is not successful enough to help the folding work, if it could be made in a larger area or other harder material.

A set of folding mold for square tessellation pattern made by the 3D printer.



A small piece of PP paper folded by the mold and hands.

5. Scenario of clothes customization service by distributed fabrication

We planned a sequence about how people process the customization service of origami clothes for interested people to evaluate the service and possibility.

5.1. Access the distributed fabrication nearby:

So far there are still a lot of Fablab or Co-working space are establishing in everywhere, maybe not all areas have these open spaces or fabrication resource. We suppose the Fablab will be popularized soon, or this service could be a fact to popularize the Fablab. The Fablab where provides the service should be equipped the laser cutter, handhold 3D scanner and the pattern system as described in the sections of 4.2, 4.3, 4.4.

5.2. Generate clothes pattern by origami system

Firstly, the Fablab staff can use the handhold 3D scanner to catch the 3D data of customer's upper body, and input to the parametric pattern system to generate the clothes pattern for laser cutter. The patterns will separate into two files, one is the mountain fold pattern, another one includes the valley fold pattern and outlines.

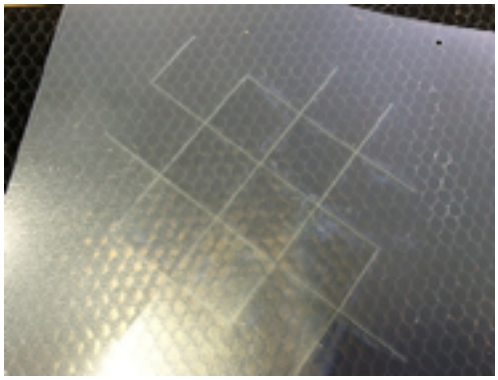
5.3. How the laser cutter of two-sides incision works

5.3.1. Input the files to the laser cutter, the laser cutter will process the cutting on both sides in the same time.

5.3.2. Due to the carving power is low, the laser beam won't pass the material when making incisions.

5.3.3. Before the final outlines cutting, mountain laser carrier will move to the corner to avoid being damaged by the valley laser carrier. The valley laser carrier will do the final cutting but leave several points to keep the pattern on the material.

5.4. **Fold and add accessory:** The Fablab Staff cut down the pattern, and apply folding tool on the pattern to make the origami fold. The origami clothes may need zipper, buttons, inner material and other clothes accessory as most clothes.



Simulate the valley fold on the one side of PP paper.

6. **Suggestions for further study:** This research integrated several technologies to help forward the alternative clothes without relying on the mass manufacturing and maintaining by wash. Even lack of few critical parts to complete the service design, but we listed them for other interested person to regard.

6.1. **Folding aid tool:** Although we tried to develop the folding mold by the 3D printer, but a faster and efficient tool is expected, such as a larger folding mold made by metal or with heating function will complete the folding faster and endure the shape longer. Somehow this tool may increase the cost for the service provider, but this depends on how huge if the benefit from the origami clothes. Besides, the smart material may help the problem with using the folding tool.

6.2. **Laser cutter with low power, large work area and dual beam carrier.** The prototype of laser cutter for origami incision needs in the previous to be built and verified. So far, the regular laser cutter still cost much for most Fablab, but the prototype without automatic detecting of focal distance and strong power won't cost so much and easy to be built as other open machines.

6.3. **Smart paper material.** A kind of smart paper material suitable for the manufacturing service needs to be developed. It should be easy to be decomposed, waterproof and durable for one or two weeks. The performance of easy to be folded is also important. The smart material can help hands-free folding by applying the difference of temperature or moisture is possible. That means applying heat or spraying moisture may active the folding effect after origami incision.

6.4. **The goal of this origami clothes is not to replacing traditional fabric clothes.** In the short term, even the barrels of origami clothes could be solved, this alternative product won't replace the using of fabric clothes, but its potential to reduce water pollution from clothes wash and recycled clothes can be expected. Origami clothes is just the transitional product to challenge the issues caused by the fabric clothes and its industry, include labors, pollution, consumption and waste. An advance and smart fabric by distributed fabrication to match our goals will be better solution than origami clothes.

6.5. **The other potential from digital design and distributed fabrication.** Except the comparison between the fabric clothes and origami clothes, other possible effects come with the service type should be considered. Not only consumers will be liberated from the restriction mass manufacturing, the designers or makers will be benefited from the open design and service type.

6.5.1. Design: The open design of clothes pattern by the algorithms system will attract and enable more designers or consumers without design background to

contribute their ideas or access product by the distributed fabrication. In this model of supply and demand, designers are not making and selling product, but design data and system.

6.5.2. Fabrication: Now many Fablab and co-working space are trying to attract people by many open product to improve their utility rate, but lack off the personal life necessaries, such as clothes. The huge consumption of clothes by distribute fabrication will bring significant business and rise for these makers or space operators. Somehow the appropriate material, service sequence and system are not available. We hope the start of research can attract more people to engage in the fabrication service and related material development.