

Bespoke and Repetitive:
Converging Technologies in the
Design of Custom Products

Zerong Yang

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Design

University of Washington

2022

Committee:

Jason O. Germany

Sang-gyeun Ahn

Justin Thoreau Lund

Program Authorized to Offer Degree:

School of Art, Art History, Design

©Copyright 2022

Zerong Yang

University of Washington

Abstract

Bespoke and Repetitive:
Converging Technologies in the Design of Custom Products

Zerong Yang

Chair of the Supervisory Committee:

Jason O. Germany

Department of Design

The growth in Industry 4.0 marks a change in some ways that products will be created as well as the ways in which professions like industrial design will continue to grow. Advances in technology, data, and analytics will increasingly give designers the ability to develop customized or bespoke products for a range of end-users. Specifically, the intersection of 3D surface scanning, generative design, and digital fabrication could trigger this growth.

This thesis examines how the intersection of these technologies is currently being leveraged by designers, identifies growing opportunities and attributes for bespoke solutions, and envisions a new process for designers to create custom products.

Contents

1. Introduction -----	2
2. Background -----	6
3. Research -----	14
4. Paradigms of Manufacturing -----	26
5. Design Experiment -----	40
6. Conclusion -----	59
7. Reflection -----	62
8. Bibliography -----	64

1. Introduction

The traditional ways of designing customized products require a relatively larger amount of time and cost but the potential growth in personalization is coming as the result of a set of advancing and potentially disruptive digital design tools that have been evolving over several decades.

This shift in opportunity as well as the convergence of technologies can broadly be considered to be part of a larger growth in Industry 4.0 [1]. This growth in Industry 4.0 marks a change in some ways that products will be created as well as the ways in which professions like industrial design will continue to grow. Many design professions have their founding in the industrial revolution and the division of labor from design and production but perhaps none more than the field of industrial design [2].

As industrial designers navigate the 21st century, they may find more in common with the crafts people they replaced in Industry 2.0 as a movement from mass production to mass customization and ultimately individualized and bespoke products emerges.

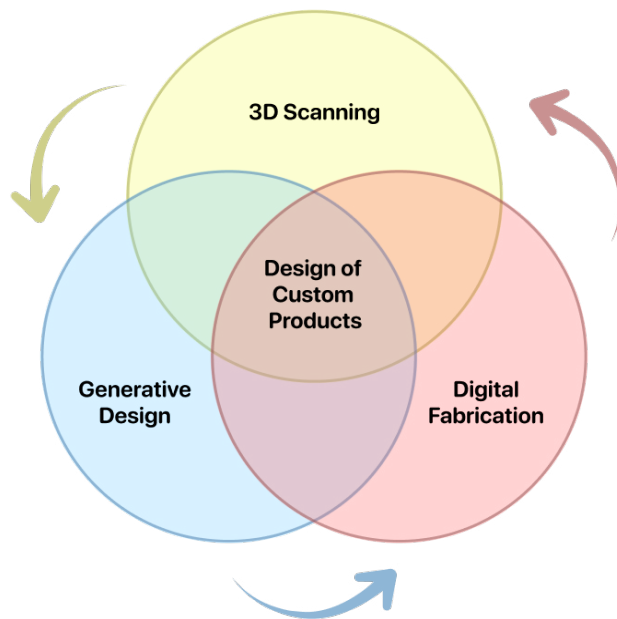


Image 1.1

The converging technologies

Although researchers have proposed the idea of the bespoke designer over the years [3] the continued advancement of various technologies have brought the reality of this design approach closer today than ever before.

Specifically, the growth of 3D surface scanning, generative design and digital fabrication have come to impact product design in different ways yet the intersection of these three technologies could trigger a growth in designing for individualize and custom products.

Although these tools provide a growing opportunity in product design there are also challenges as an approach to design for the custom and individualized may not be effective for all products or every product category.

To be a truly 'collaborative customization' [4] the product type and co-creative effort has to leverage the advantages of the technology with new design methods. The overall advantages of this approach have the potential to yield better fit with the user, improved performance, error reduction, increased user satisfaction and deliver a more sustainable product life to name a few.

2. Background

As a means of highlighting the way surface scanning, generative design and digital fabrication are converging in support of bespoke design, the following section reviews some of the background and advances in these individual technologies.

2.1 3D Surface Scanning

3D scanning has been in use starting as early as the 1960's but in recent years the range of scanning hardware, reduction in price and improvements in software have made this technology more accessible to industrial designers as well as the average end user.

In the context of this research, 3D scanning is a way to capture a physical object's surface, exact size and shape as a form of digital data or 3- dimensional representation. In the broad sense, there are a range of applications for this type of scanning, specific to the field of product design the content that is often being scanned falls into three types including surface data from environments, objects and people with the two most common applications being reverse engineering or human body scanning.

In the particular application of designing for ergonomic fit, scanning end users body or bodily features is increasingly leveraged in two main ways. The first way is finding the most suitable design for a wide range of people based on a variety of 3D scans and can include a multiple step process [5] often utilizing a database like the CAESAR project [6]. The second approach is made-to-measure products for specific users. Based on the 3D scans of the user's body, a bespoke product may be made to custom fit the user. These kind of design methods have been growing within the fashion and apparel design industry [7].

The growth of scanning and its application is connected to advances in the types of scanning technology. 3D scanning devices are divided into two categories: contact and non-contact scanners. The non-contact scanners that capture geometry through lasers and optics, computer vision, photogrammetry, light detection and ranging (LiDAR), and imaged based techniques are the area relevant to this discussion as the access to these devices is changing. Although LiDAR type scanners have challenges [8] several of these challenges are being overcome through improvements in software making them more useful for product design [9].

Perhaps the biggest impact on future bespoke design is the ability for the average end user to scan and collect surface data to collaborate with a designer in the development of a customized product. Currently, mobile devices like the iPhone and certain consumer tablets have the ability to collect surface scanning data thus eliminating the costly hardware barrier.

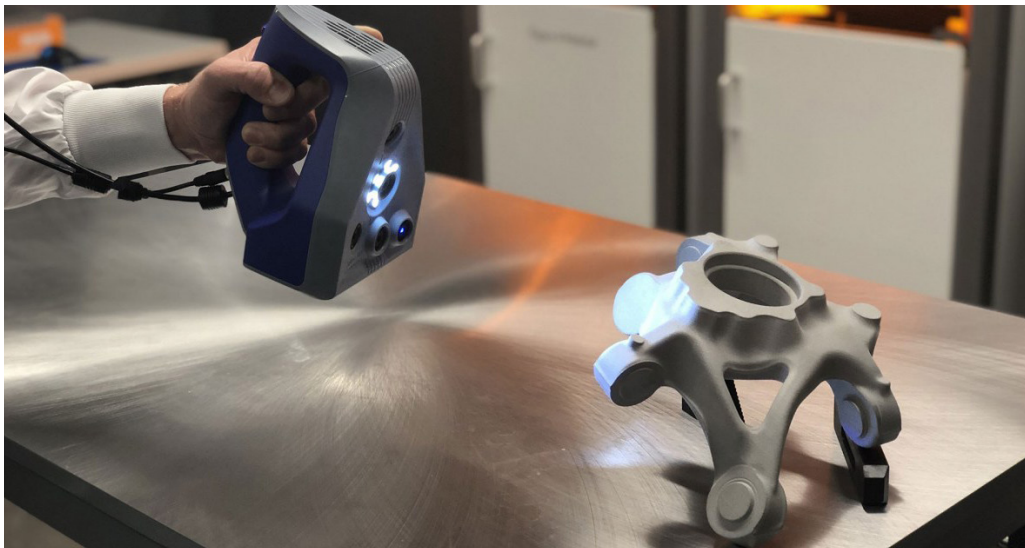


Image 2.1

3D scanning for reverse engineering

<https://www.artec3d.com/learning-center/how-3d-scan-object-portable-structured-light-scanner>

2.2 Generative Design

Generative design is a technology in which 3D models are created and optimized by computer software. It has been an important tool since 1970's and was adopted in computer science, architecture, engineering, and construction. In recent years, it has become popular in product design disciplines [10] and a portion of this growth is directly tied to the advances in the software itself.



Image 2.2

Generative design in product design - stool

<https://www.rit.edu/spotlights/stool-voronoi-generative-design>



Image 2.3

Generative design in architecture

<https://bdaa.com.au/generative-design-generates-results/>

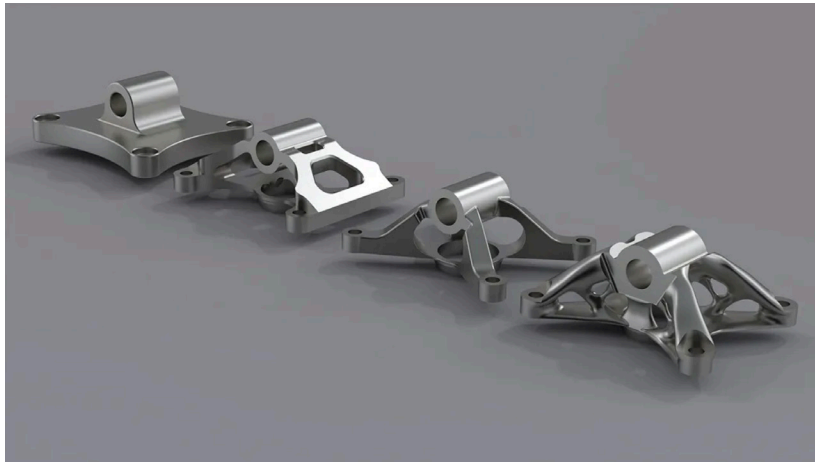


Image 2.4

Generative design in engineering

<https://www.plm.automation.siemens.com/>

There are a range of generative and parametric design software on the market including Autodesk Fusion 360, Solidworks Topology Optimization, Grasshopper in Rhino, and nTopology. In some cases, and certain applications, these programs can require significant labor investment and levels of visual coding. That being said, the future of these platforms is becoming clearly more accessible to designers over time will be disruptive. This is particularly the case when one considers how automation of any kind, might impact a market or profession. None more relevant that the design of customized or in some cases the design of mass customized products that leverage end user input either directly or indirectly. Ultimately it will be a balance as disciplines ranging from architecture [11] to jewelry design [12] explore the potential between automating portions of the design process to better support customization efforts.

When it comes to product design, these systems will clearly present advantages to the designer as it will allow some end user parameters to be added as a potential constraint in the generative platform. This coupled with the use of generative design as a means of increasing design concept output while balancing time and costs to the design team, bringing the cost of custom products within reach of the everyday consumer.

2.3 Digital Fabrication

Digital fabrication is a set of tools for prototyping or production and is commonly used in several design and engineering fields. These systems of additive and subtractive digital tools have been described as disruptive in their own right and are a part of the Industry 4.0 shift.

Like the two technologies covered in the previous sections, digital fabrication has evolved over decades to become distributed and in some cases desktop solutions. From laser cutting and CNC to a range of 3D printing platforms, each of these is distinctly data and computationally driven.

As the machines have evolved so have the sources of the data that drives them. Inherently flexible in their application compared to tooled mass production methods, design practitioners have continued to move from utilizing these for prototyping to actual product production in the case of bespoke solutions. Digital fabrication has had a long history of use for producing customized product solutions but it has scaled up to include building custom houses [13] or down to deliver vascular tissue for medical applications [14]. Digital fabrication and in particular 3D printing, has decentralized and distributed the source of parts combined with eliminating the barrier of tooling costs that are associated with mass production while allowing repeated fabrication by the end user or designer.

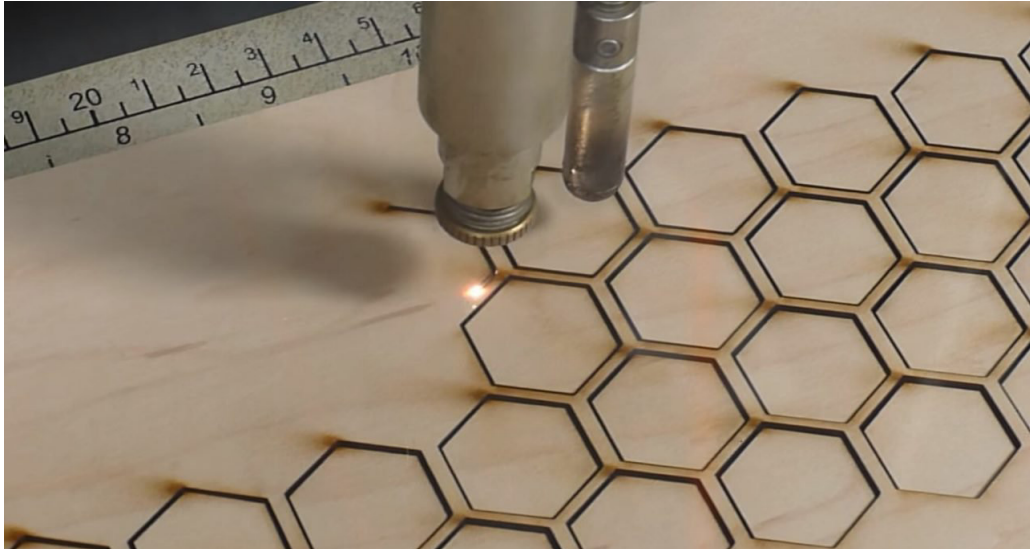


Image 2.5

Laser cutting

<https://bb2careers.org/>

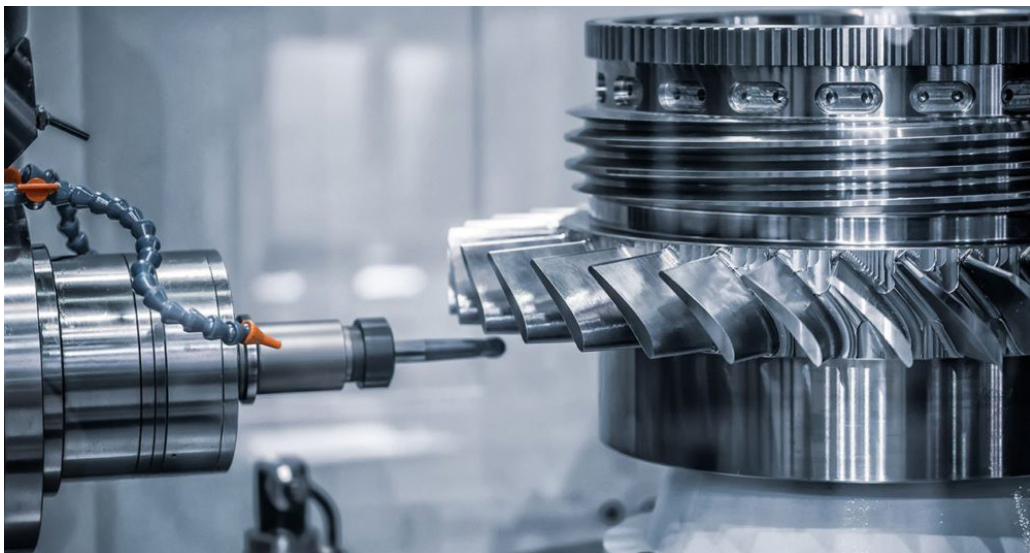


Image 2.6

CNC machining

<https://www.rapid-direct.com/knowledge-base/article/how-cnc-machining-is-used-in-aerospace/>



Image 2.7

3D printing

<https://theconversation.com/five-3d-printing-myths-119887>

3. Research

Primary and secondary research was conducted to examine how designers currently leverage the three technologies and identify which categories of custom products have more potential opportunities.

3.1 Interviews

To better understand how individual designers and design groups were approaching the use of these technologies, I interviewed several design teams who were creating bespoke solutions in a range of markets.

3.1.1 Animal Prosthetics

An interview with designers from Dive Design revealed that they are utilizing 3D surface scanning in conjunction with generative design methods to develop bespoke animal prosthetics for individual pet owners [15].

Image 3.1

Full-limb pet prosthetics

<https://www.dive-designco.com/>



The traditional way to create a single full-limb prosthetic takes a minimum of 15 hours to complete. The process began by sealing the patient mold to prevent leaks and then mixing plaster to create the positive. Sheets of plastic were heated and wrapped over the plaster positive, then trimmed and shaped further. Finally, foam was added along with hardware and the leg. [15]



Image 3.2

3D scanning

<https://www.dive-designco.com/>

Image 3.3

Custom algorithm

<https://www.dive-designco.com/>

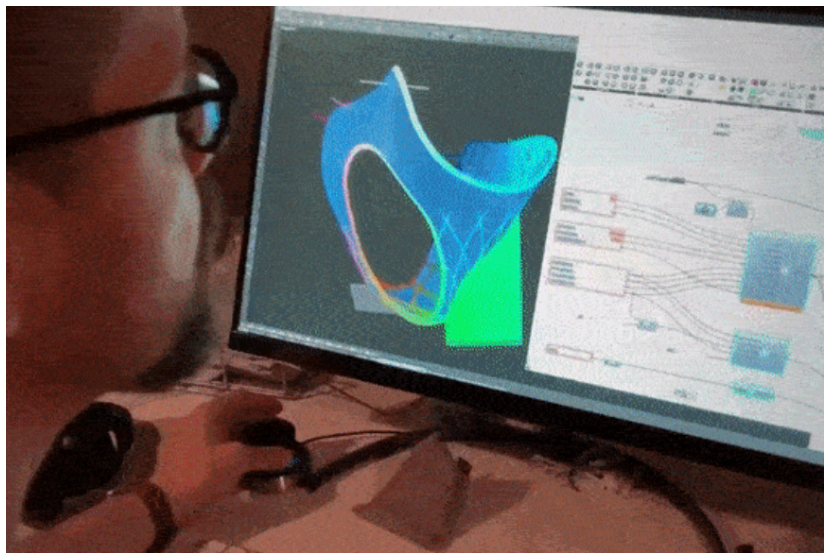
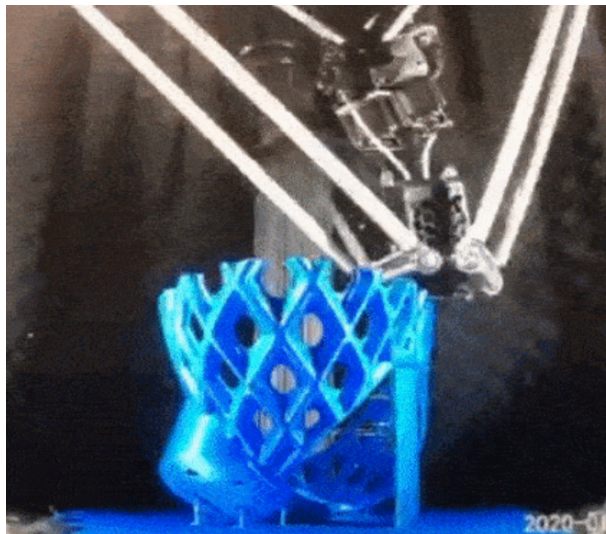


Image 3.4

3D printing

<https://www.dive-designco.com/>



For the new process, they send a casting kit to the client, and the client wraps the patient with fiberglass casting tape. The molds are sent back to the company when the tape is hardened. Then, they use an iPhone medical-grade 3d scanning app called Comb Scan to scan the molds and clean up the scans in MeshMixer. It takes 10 minutes for setting up the scans in Grasshopper and 2 minutes for processing. Through this algorithm, the finalized 3D printable models of the prosthetics are generated in 12 minutes. At last, they 3D print the prosthetic in TPU (Thermoplastic polyurethane), which is a type of flexible and elastic 3D printing filament. The custom design allows the prosthetic to be optimized for comfort, breathability, and flexibility.

3.1.2 Custom Fit Earphone

A conversation with a team member at Ultimate Ears revealed their approach to designing and developing their custom UE Pro IEM series. The process has evolved to leverage a specially developed inner ear surface scanner to collect accurate data that is ultimately used to generate 3D printed and perfectly fit in-ear monitors.

Image 3.5

Ultimate Ears
Pro IEMs

<https://pro.ultimateears.com/>



For the Professional IEMs series, there are two ways to get the digital impression of ears from the customer. Traditionally, custom in-ear monitors are created by taking a mold of the inside of the ear. The mold uses a fast-drying silicone from Westone, and it is injected into the ear cavity by an audiologist. Then the impression is scanned by a 3D scanner. The other way is digital ear scanning. The UE 3D Ear Scanner from Ultimate Ears is the only digital scanner on the market that offers the necessary precision to create custom in-ear monitors.

The next step is detailing the ear impression. They use a software called 3Shape to eliminate all the unnecessary parts of the model and then use an SLA 3d printer to fabricate the part with acrylic or resin.

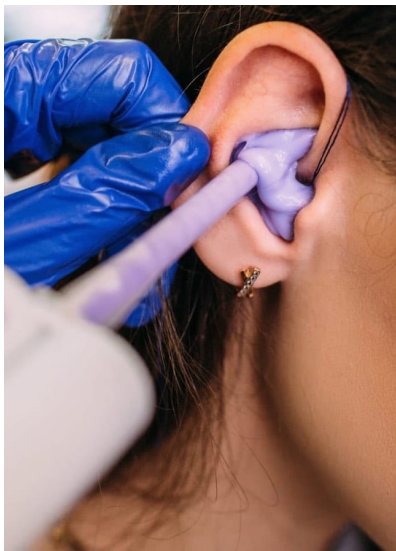


Image 3.6

Silicone mold

<https://pro.ultimateears.com/>

Image 3.7

UE 3D ear scanner

<https://pro.ultimateears.com/>



3.1.3 Human Prosthetics

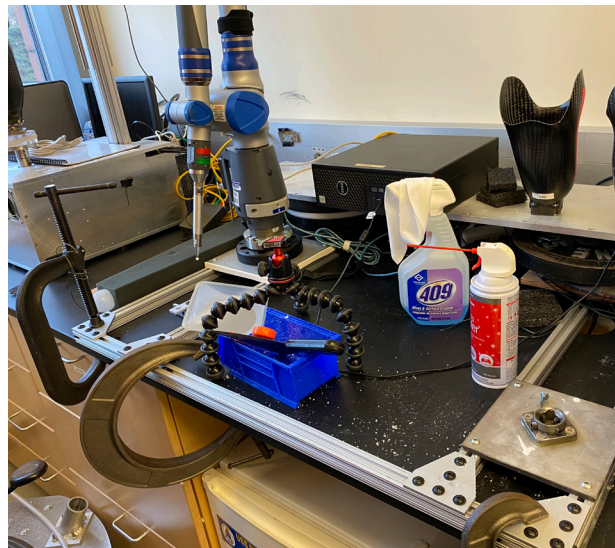
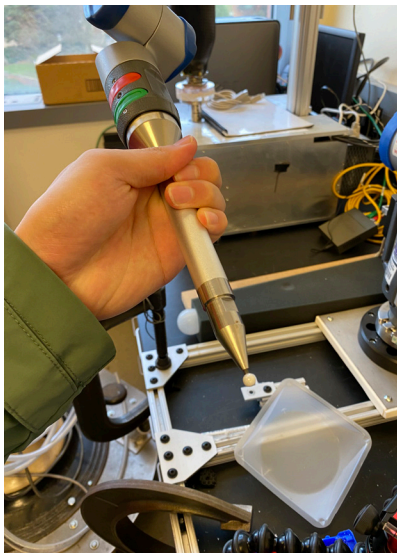
A visit to Sanders' Lab at the University of Washington provided insights into the design and fabrication of the next generation of human prosthetics.

The Sanders' Lab is creating the next generation of prosthetic scientists and researchers that will further advance the field and enhance the quality of life of people with limb loss. [16]

At the lab, One of their team members showed me the process of how they duplicate a prosthetics socket for their research project. First, they use a contact scanner to scan the inside of the existing socket, and it takes about one hour to finish because enough points have to be collected in order to create a mesh.

Image 3.8

Contact Scanner



Next, they will use a software called Geomagic Design to turn the point cloud into a surface model. An STL file will be used to create a foam positive through CNC. Then, they will use carbon fiber, nylon, and resin to make the new socket by vacuum sealing them onto the foam positive. At last, a software called OMEGA Tracer is used to convert the STL file to an AOP format, which is a standardized format for prosthetics device building. The AOP file could be sent to manufacturers for making prosthetics.

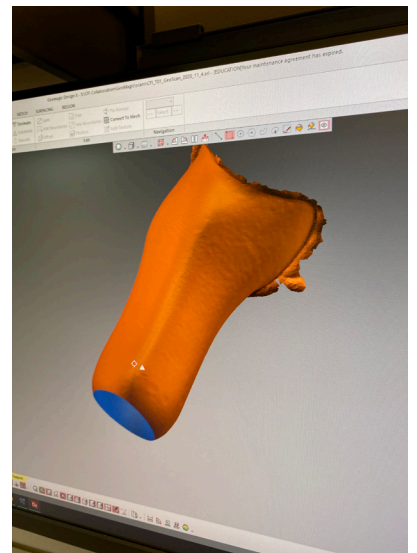
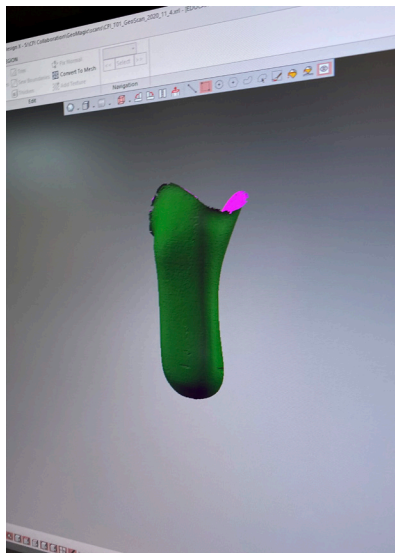


Image 3.9
Image-editing
process



Image 3.10
Foam positive



3.1.4 Findings

In each of these cases, design teams were moving from a point of data capture (scan) to CAD design (generative or conventional) to digital fabrication and in several cases there was a feedback loop generative another cycle of iteration.

3.2 Custom Products

In considering the application of these technologies in the service of a bespoke design strategy, it is clear that not all product categories or problems are best served by this customized approach. Performance, cost, time, or use are but a few of the driving factors that may delineate a product from being developed for mass production vs designed as a truly custom and bespoke device. Growth in this design approach will not only be connected to the advance of digital tools but also the types of problems that they may aid in addressing.

3.3 Categories of Custom Products

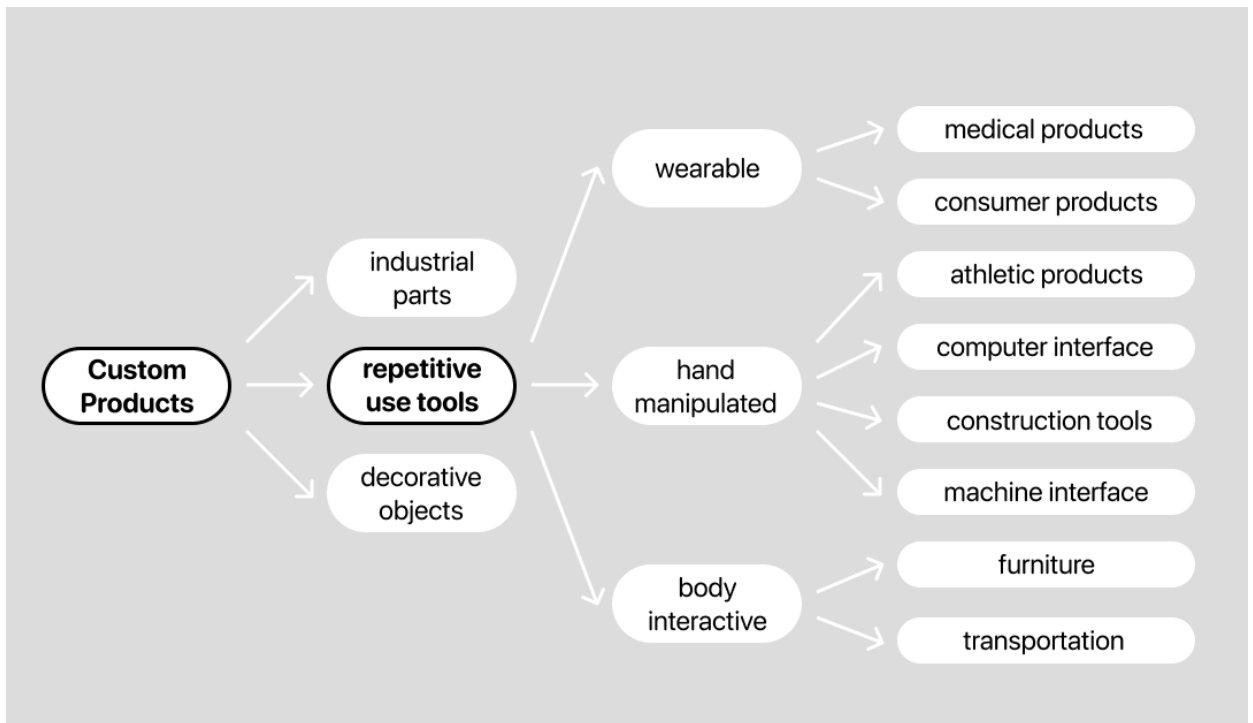
By examining how the intersection of these technologies is currently being leveraged by designers in combination with larger market, an effort was undertaken to categorized to potential for custom product into three groups: industrial parts, decorative objects and repetitive use tools.

From a design standpoint, decorative objects refer to the customization of the aesthetically variable elements like color, print pattern, and in some cases materials without impacting the geometric or functionality. Repetitive use tools on the other hand encompass a product category where the geometry, materials, and components may require unique designs to fit the individual end user and contextual application.

This category could then be classified into three sub-categories: wearable, hand-manipulated, and body-interactive. These three sub-categories aim to encompass areas of use that have the strongest room for growth in future bespoke scenarios as they all have a high degree of interface with the human body and require high level of precision in their performance as a tool.

Image 3.11

Categories of custom / bespoke products



3.4 Opportunities

As part of Industry 4.0, advances in technology, data, and analytics will increasingly give designers the ability to develop customized or bespoke products for a range of end users.

Specifically, the intersection of 3D surface scanning, generative design and digital fabrication could trigger this growth. Access to 3D scanning hardware and software will move from the designer collecting user data to the end user generating the scans themselves. This coupled with the use of generative design as a means of increasing design concept output while balancing time and costs to the design team thus bringing the cost of custom products within reach of the everyday consumer. Lastly, digital fabrication and in particular 3D printing, has decentralized and distributed the source of parts combined with eliminating the barrier of tooling costs that are associated with mass production while allowing repeated fabrication by the end user or designer.

Not all products will fit a bespoke approach but repetitive use tools show the most potential for growth in this area.

4. Paradigms Of Manufacturing

To effectively illustrate how customization has evolved over time, I analyzed the existing three paradigms of manufacturing, proposed a new approach, and created a process diagram for each of them.

4.1 Mass Production

Mass production is the manufacturing of large quantities of standardized products, often using assembly lines or automation technology. Mass production facilitates the efficient production of a large number of similar products. [17]

Interchangeability and the moving assembly lines enabled the development of mass production which provided low-cost products through large scale manufacturing. However, the number of varieties offered by such production was very limited. [18]

Image 4.1

Mass production process diagram

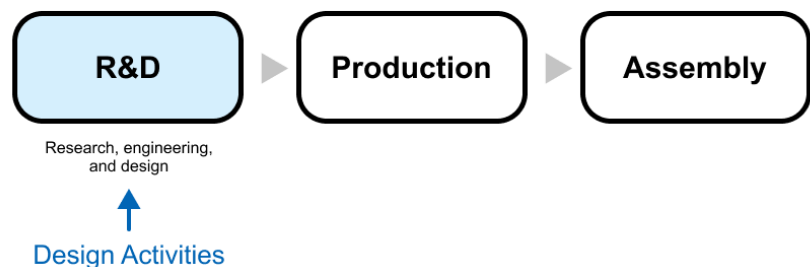




Image
Mass production,
household appli-
ances

The process diagram shows the flow of mass production. First, there are researchers, engineers, and designers creating the product. Then, the products are mass produced and assembled with a high level of efficiency through automation. Establishing an automated assembly line is capital-intensive and requires a significant upfront investment of time and resources. If there is an error in the design, an extensive investment of time and money may be necessary to redesign and rebuild mass production processes. [17] Products will be warehoused and delivered until retailer purchase or customer purchase.



4.2 Mass Customization

Mass customization is the process of delivering market goods and services that are modified to satisfy a specific customer's needs. Mass customization is a marketing and manufacturing technique that combines the flexibility and personalization of custom-made products with the low unit costs associated with mass production. [17]

In the late 1980s, global competition and consumer demands for high product variety led to the development of mass customization. Manufacturers designed the basic product architecture and options while customers are allowed to select the assembly combination that they prefer most. Product family planning enabled manufacturers to share certain common components across the products in the family so that economy of scale is achieved at the component level. Flexible and reconfigurable manufacturing systems are utilized to create high variety in the final assembly through combinational assembly, thus achieving the economy of scope. [18]

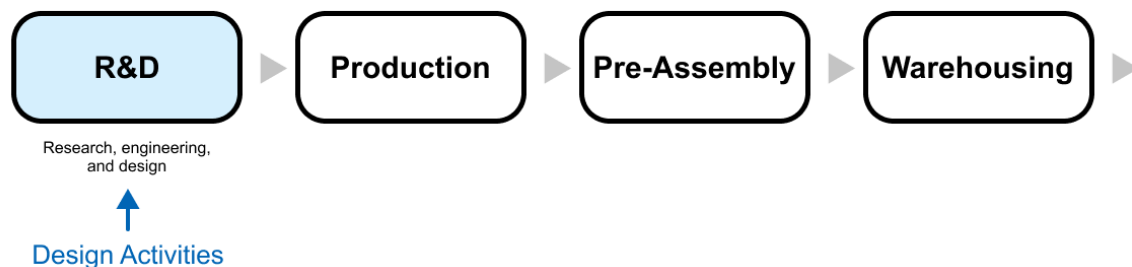


Image 4.2

Mass customization process diagram

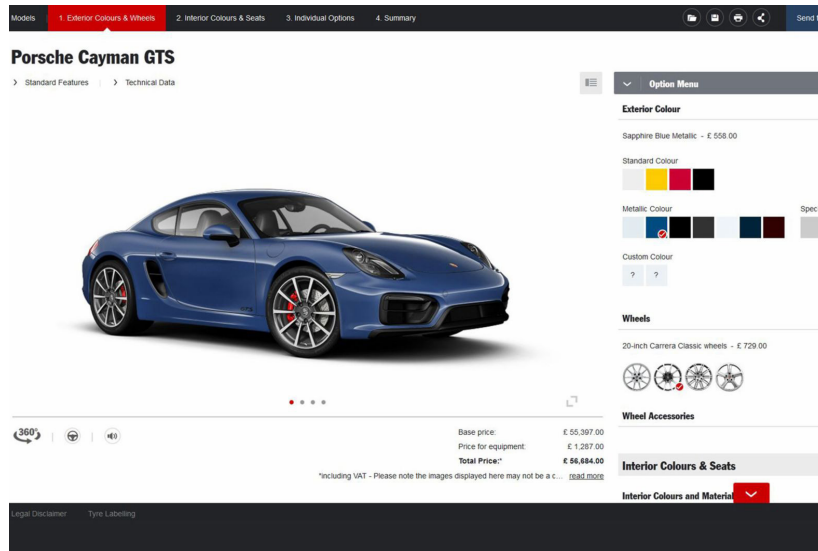
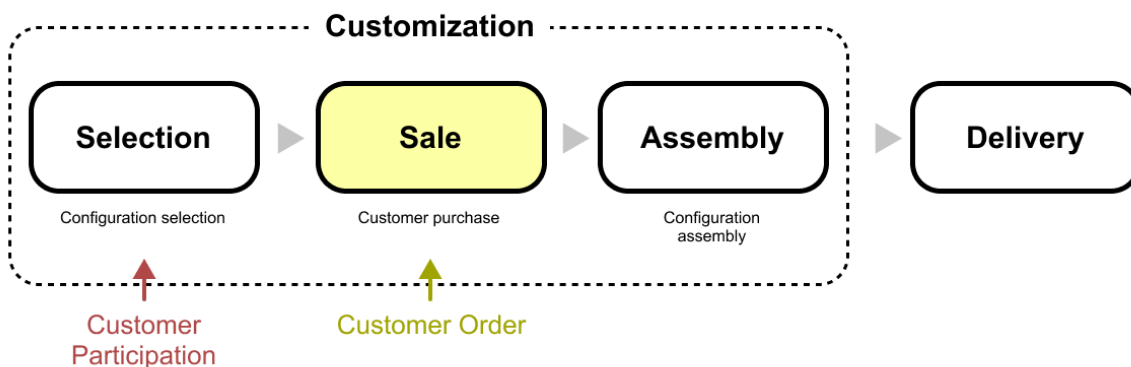


Image 4.3

Mass customization, car configuration

The first four steps are similar to the mass production. All the parts are mass produced at front. Instead of assembling the entire product, mass customization provides a low level of customization, which allows the end users to make configuration selection. The products are assembled based on the configuration and delivered to the customer.



4.3 Personalized Production

The personalization of products tailored to the individual needs and preferences of consumers. Customers create innovative products and realize value by collaborating with designers, manufacturers, and other consumers.

This co-design process is enabled by an open product architecture, on-demand manufacturing systems, and responsive cyber-physical system involving user participation in design, product simulation/certification, manufacturing, supply and assembly processes that rapidly meet consumer needs and preferences. [18]

Image 4.4
Personalized production process diagram

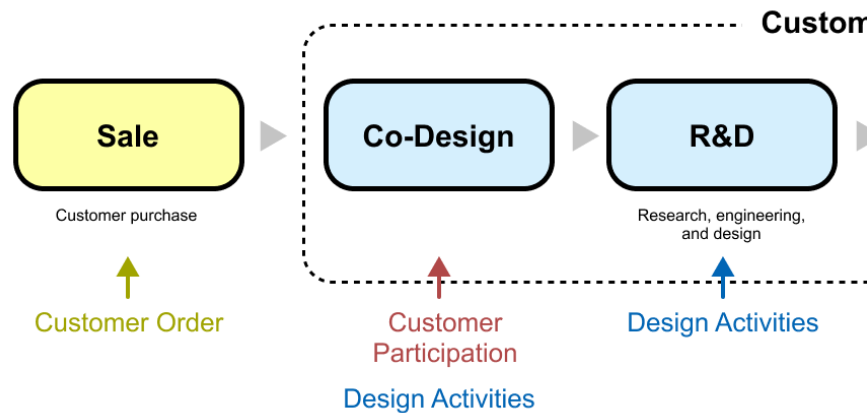


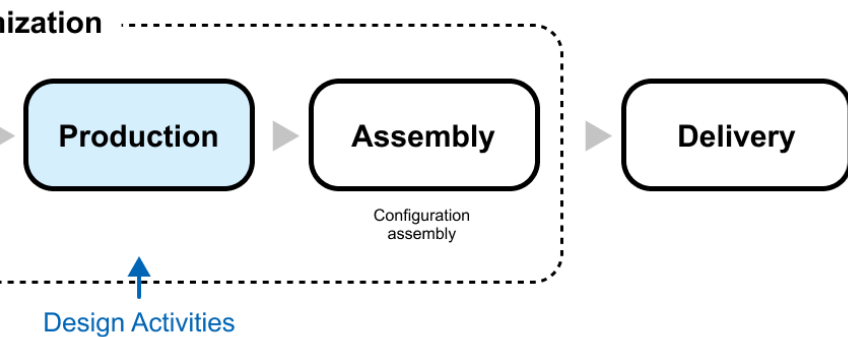


Image 4.5

Custom Ring Design

<https://lovbe.com/>

Different from mass production and mass customization, all the design activities in personalized production happen after customer make purchase. Consumers are participating in the design process at different levels. There will be research into the design and engineering. Both designers and the users will be learning a significant amount during the design process. Visualization tools are needed to aid the consumer in understanding the ramifications of design choices before production. [18]



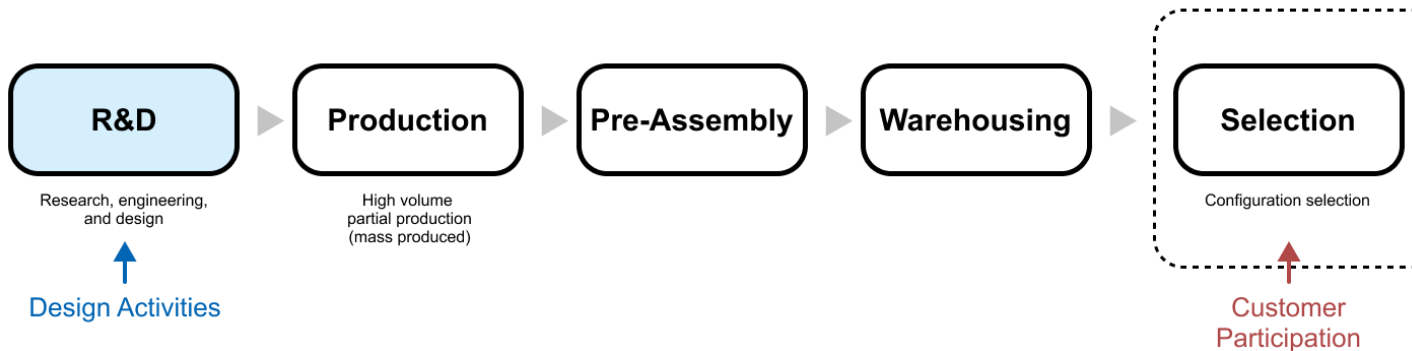
4.4 New Process - System Customization

I proposed a new process called system customization. The first four steps are the same as the mass customization, but there are two new steps in customization. Co-design and production. Part of the product will be mass produced, and the other part of the product will be customized designed and digitally fabricated. The two parts will then be assembled and sent to the customer.

It has a low part cost for the mass produced parts but provides a relatively high level of customization. Compared to mass production and mass customization, it has lower quantities and higher costs for design, production, and assembly. Compared to personalized production, it has higher efficiency and lower cost.

Image 4.6

System Customization process diagram



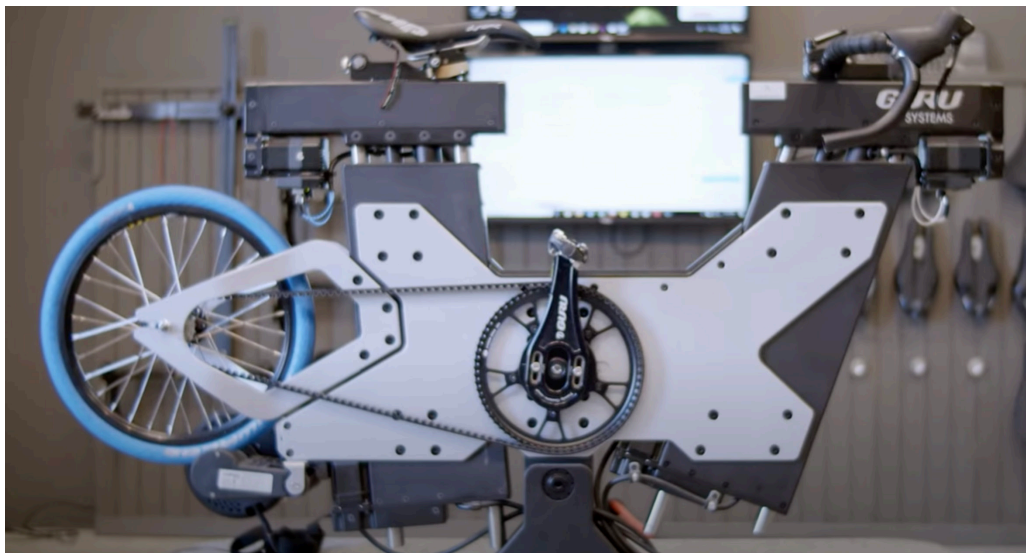
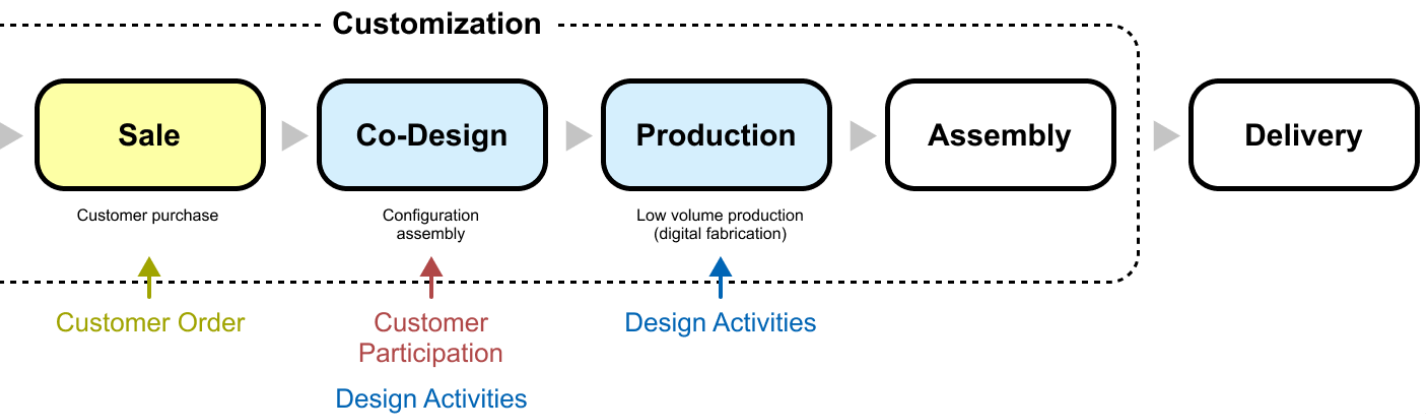


Image 4.7
 Bike fitting machine to collect user data for bespoke design



4.5 Comparison

Most of the products are produced through the three existing paradigms of manufacturing, which are illustrated in the diagram below using a volume-variety relationship. I added system customization on the diagram to compare with the others. It has a medium production volume because some parts are mass produced, and data collection, generative design, and digital fabrication can also improve efficiency. It also has a relatively wider variety because of the customization part.

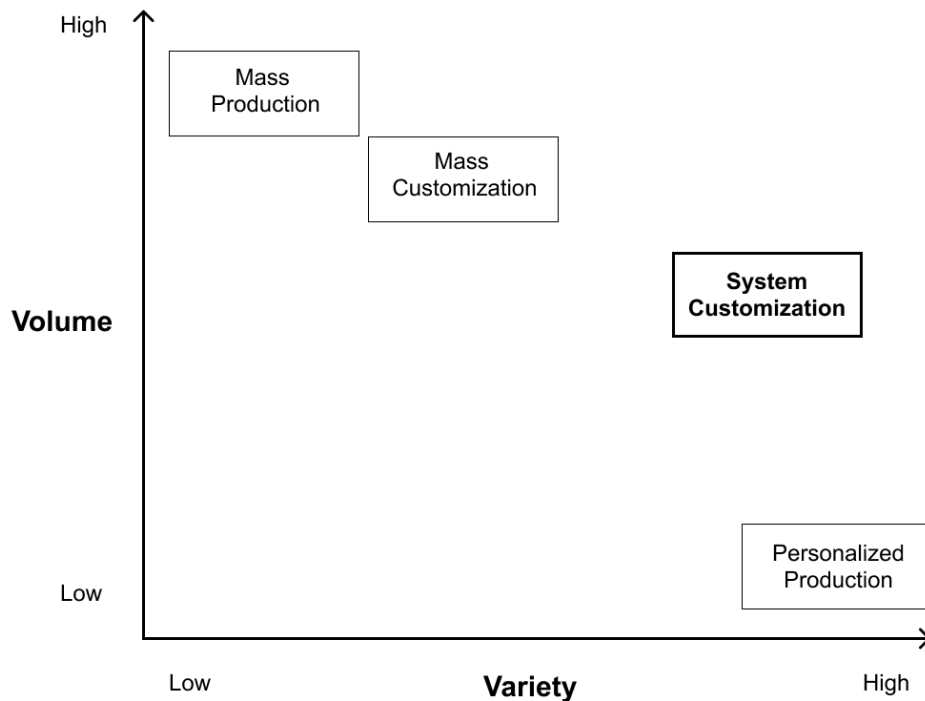


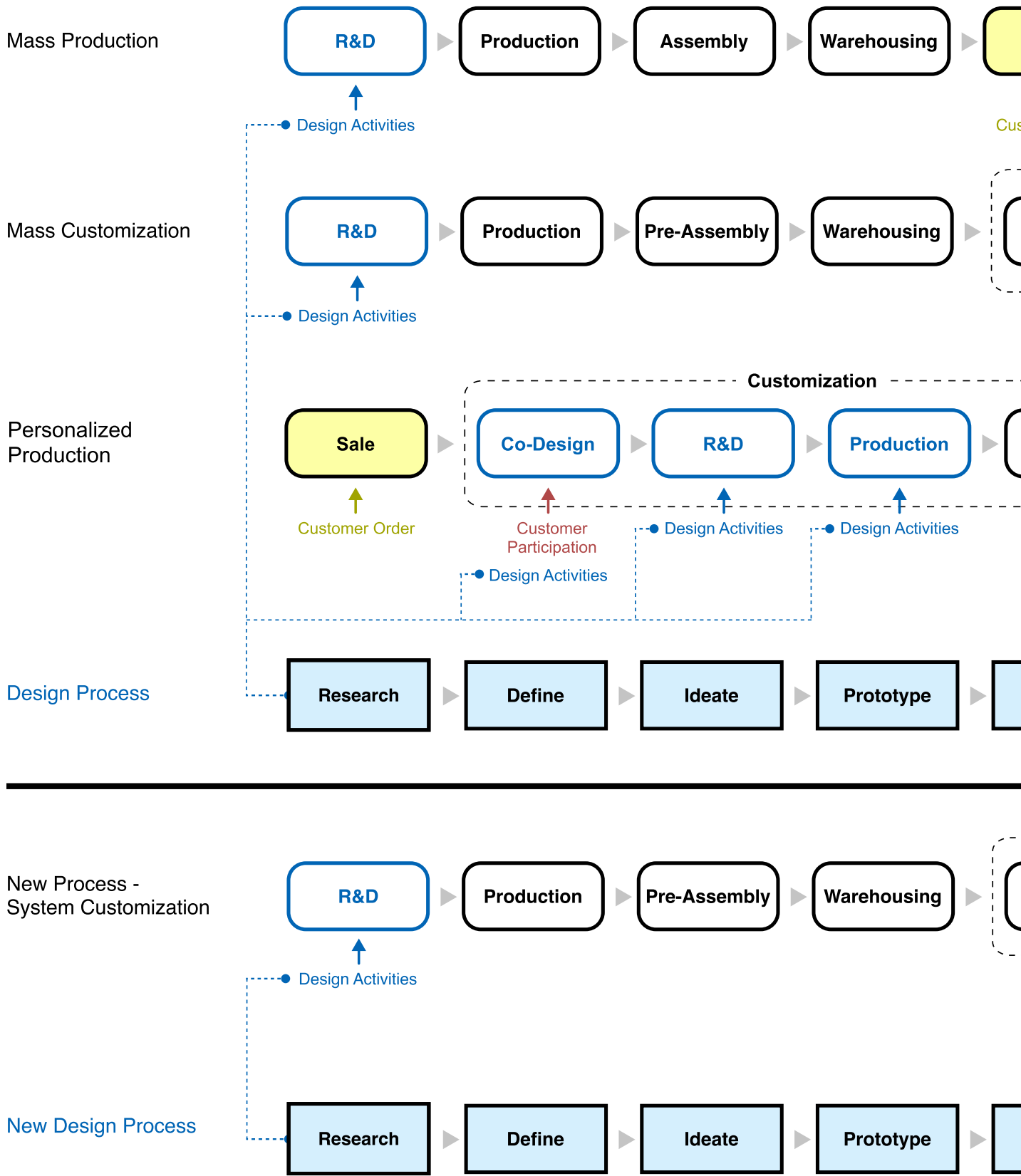
Image 4.8

Production - Variety vs. Volume

For the process diagrams on the next page, the yellow blocks are where customers make the purchase. The blues are where we have all the design activities.

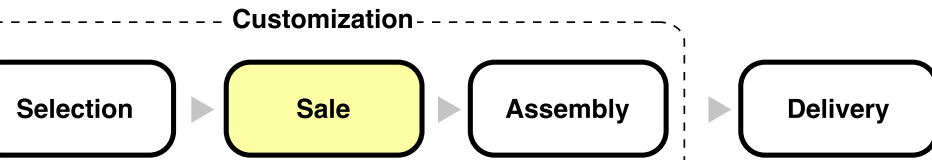
All the industrial design activities are front-loaded for mass production and customization. After production, the design cannot be changed, and the products stay the same. Mass customization just has more elements in customization. For personalized production, design activities happen after the customers' purchase, and customers participate a lot in the customization process.

For system customization, design activities happen at the start and after the customer orders. The designers are also involved in customization based on data collection. There are three new steps to help make better custom products. Data collection, generative design, and digital fabrication. The role of designers will be to design unfinished objects. These will be products which are incomplete without the consumer's expertise since they will require unique decisions and inputs from consumers. [19]



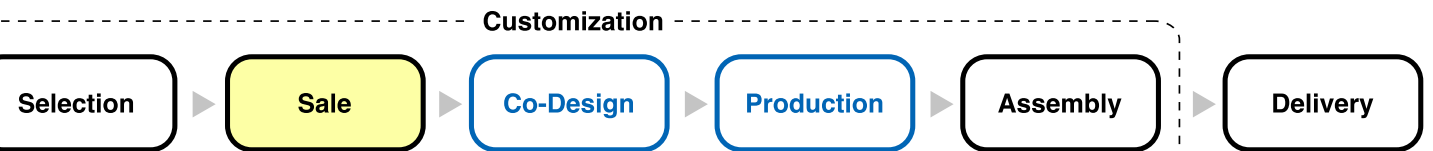
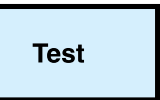
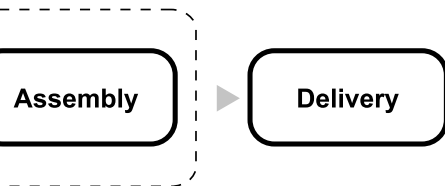


↑
Customer Order



↑
Customer Participation

↑
Customer Order

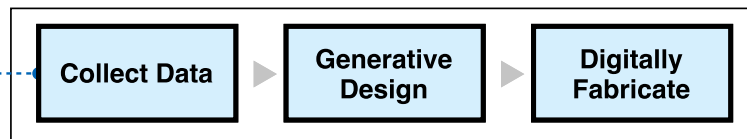
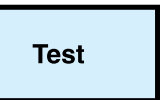


↑
Customer Participation

↑
Customer Order

↑
Customer Participation

↑
Design Activities



• Design Activities

• Design Activities

• Design Activities

5. Design Experiment

To show how system customization helps to design customized products in a better way, I started to work on a design experiment with the use of the data collection, generative design, and digital fabrication.

5.1 Problem

I selected gaming mouse as the object to design, because I am a gamer myself and I realize I have some type of wrist pain, so I did some research on the market and the wrist health problems.

There is no bespoke mouse in the market, even esports players are using mass-produced gaming mice. PC gamers have a larger chance than normal computer users to get repetitive strain injuries due to the heavy use of the mouse. A lot of professional players retired because of hand injuries.

Ergonomic wrist rest pads are commonly being used to alleviate painful symptoms but would exacerbate the condition because of the further compression to the median nerve through the carpal tunnel of the wrist. Conventional ergonomic mice are recommended by most physiotherapy physicians, yet are not suitable for gaming due to their different moving curves.



Image 5.1

Ergonomic mouse



Image 5.2

Wrist rest pad

Carpal tunnel syndrome is a common condition that causes pain, numbness, and tingling in the hand and arm. Too much compression to the carpal tunnel area combined with a lot of repetitive motions can lead to carpal tunnel syndrome, and it can be permanent damage if left untreated.

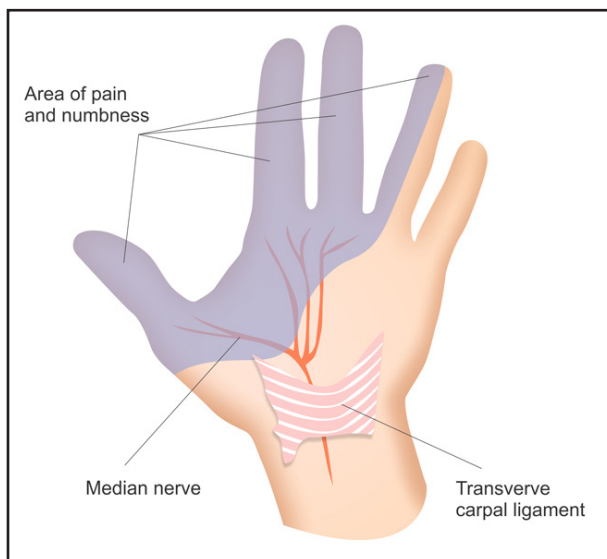


Image 5.3

Carpal tunnel syndrome

<https://fairviewadc.com/rehabilitation/carpal-tunnel-syndrome-faqs/>

Image 5.4

Forearm muscle fatigue

<https://pacificergo.com/5-tips-to-prevent-wrist-discomfort-while-using-a-mouse/>



If the mouse user holds the hand in an extended position and keeps the same position for a long time, the activated muscles in the forearm will get tiring and even painful.

From a Logitech proprietary research in 2019, 15% of computer users in the US experience pain or discomfort in the fingers, wrist, forearm, hand, shoulder, or elbow on a daily basis. There were over 2 billion computer users around the world in 2019. Thus, the estimated population will be about 300 million people worldwide.

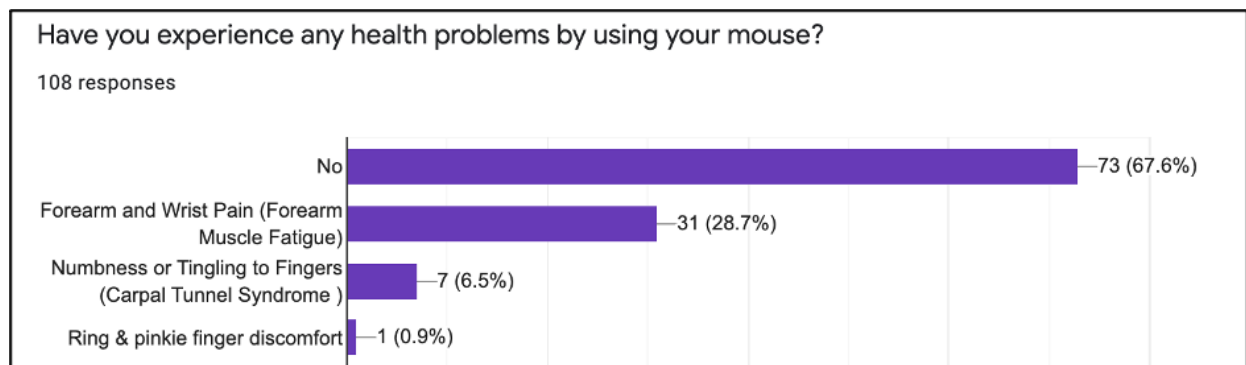
5.2 Survey

To further explore how gamers use their mouse, I created a gaming mouse survey and sent it out to different gaming communities. I received effective 109 responses: 56% percent of them play games almost every day, and 36% of them play games for more than 4 hours each time. More than one-third of them indicate that they have forearm and wrist pain (muscle fatigue) or numbness and tingling in fingers (carpal tunnel syndrome).

From the survey, most gamers have not done any customization to their mouse. A few people did some custom paint and attached non-slipped grip stickers. A few people changed the paracord and mouse skates. Three people reduced the mouse weight, and one person added some weight. Although most people do not customize their mouse, there are still needs for customization on the weight and components of the mouse. It might not be easy for normal users to customize the shape of the mouse. A lot of gamers have trouble choosing the right mouse, and it is hard to find a suitable mouse without testing it in hand. More than 70% of people changed their mice within two years, one of the reasons may be the

Image 5.5

Gaming mouse survey



“Typically swap feet to tiger ice. Have swapped switches on mice that need it. On heavy mice I do weight reduction mods.”

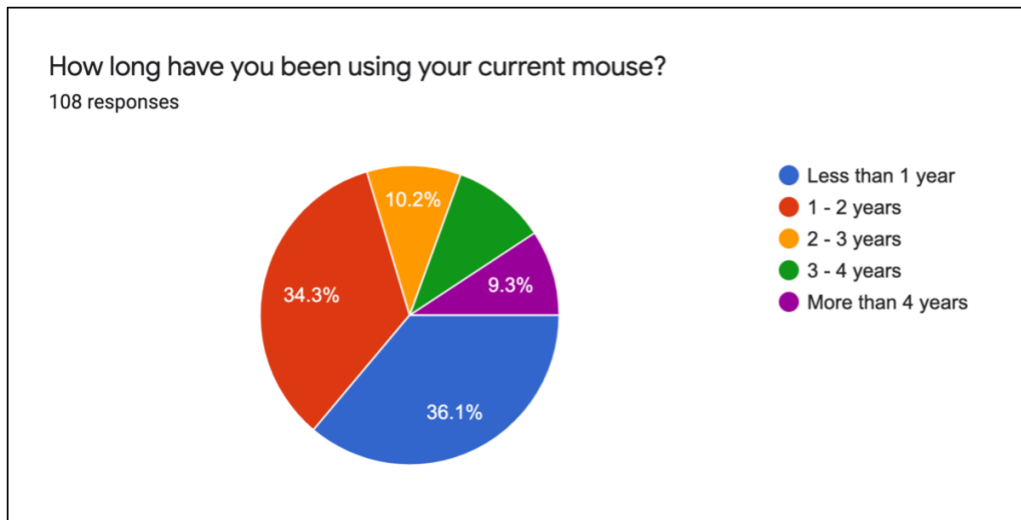
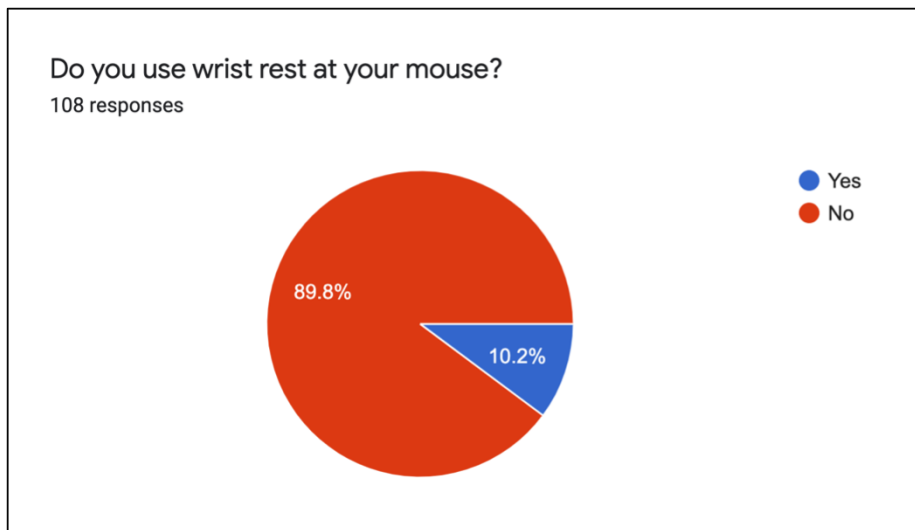


Image 5.6

Gaming mouse survey

Image 5.7

Gaming mouse survey



5.3 Solution

Based on the problem listed in the previous section, the optimate solution should have a palm rest and a customized mouse shape to reduce pain and maximize comfort.

The palm rest prevents forearm fatigue and carpal tunnel. It has a constant slope from mouse to desk to keep the wrist straight and does not end right at the carpal tunnel area causing the extra pressure.

The customized mouse shape fits the user's hand perfectly. The shape of the mouse and palm rest could be customized based on the user's palm shape, finger positions, grip styles, and weight tendencies. It provides the maximum comfort and eliminates unnecessary muscle activations in the fingers, hand, and forearm.

A five step process is created for designing the Customouse.

Image 5.8

Five step process

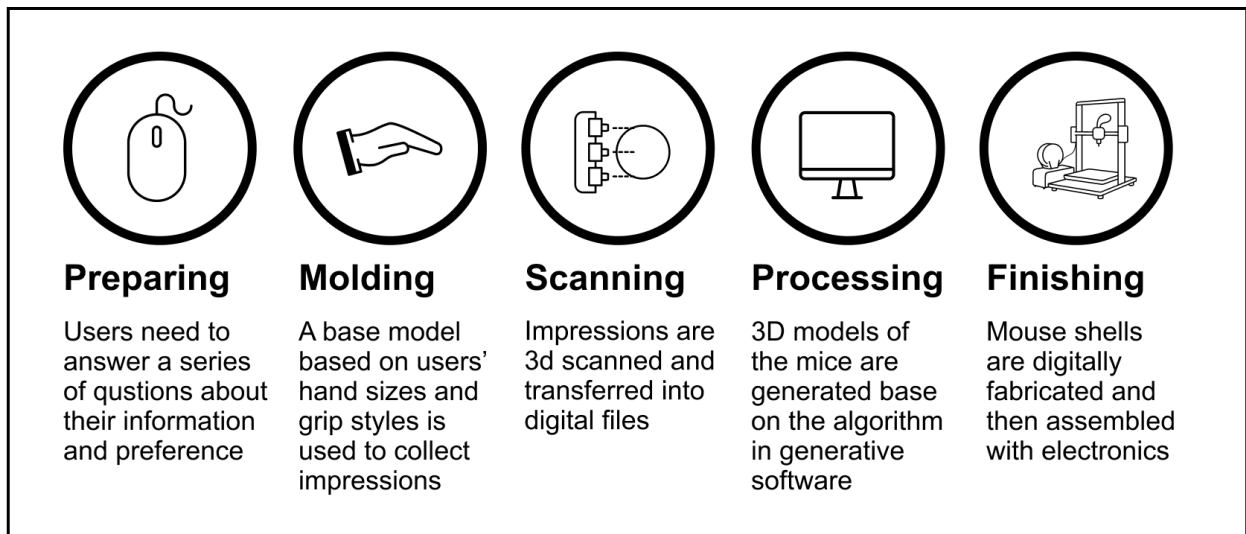


Image 5.9
Regular mouse

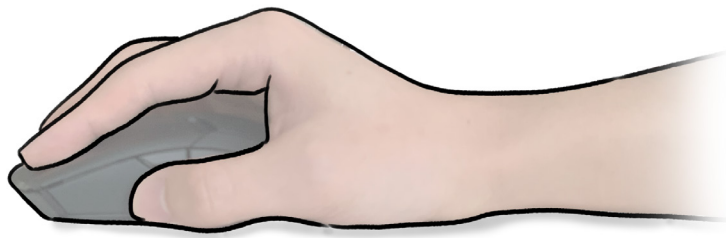


Image 5.10
Custom mouse



5.4 Data Collection

5.4.1 Preparing

In order to collect users' data for customization, I identified all the necessary factors that affect mouse user experience.

A website was built for users to answer the following questions:

- Hand size or length
- Grip styles (palm grip, claw grip, fingertip grip)
- Left or right-handed using the mouse
- Types of games played (FPS, Moba, Strategy, RPG)
- Health concerns of the mouse hand
- Wrist support type
- Number of side buttons
- Wired or wireless connection
- Desired mouse weight and patterns
- Material of the mouse shell

Based on their responses to the above questions, the result will recommend a mouse fitting kit type which includes one of the 12 base models of the mouse with a layer of thermoplastic on the top.



Image 5.11

Palm grip

<https://www.razer.com/>

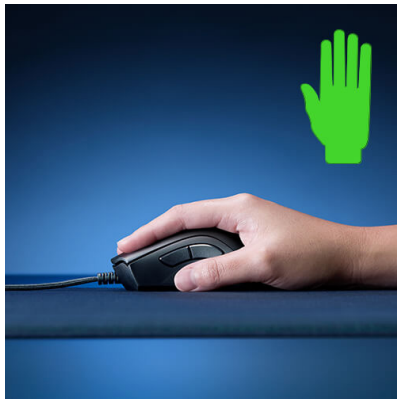


Image 5.12

Claw grip

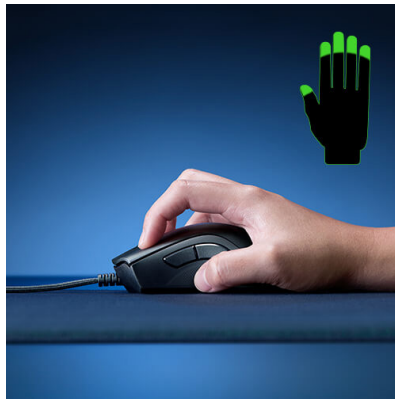


Image 5.13

Fingertip grip

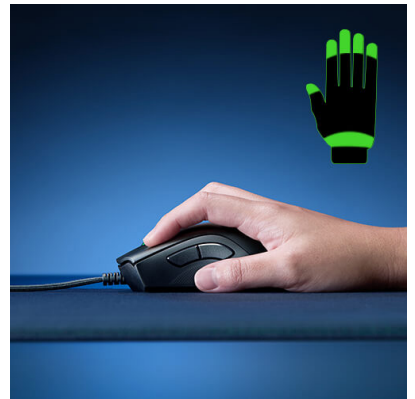
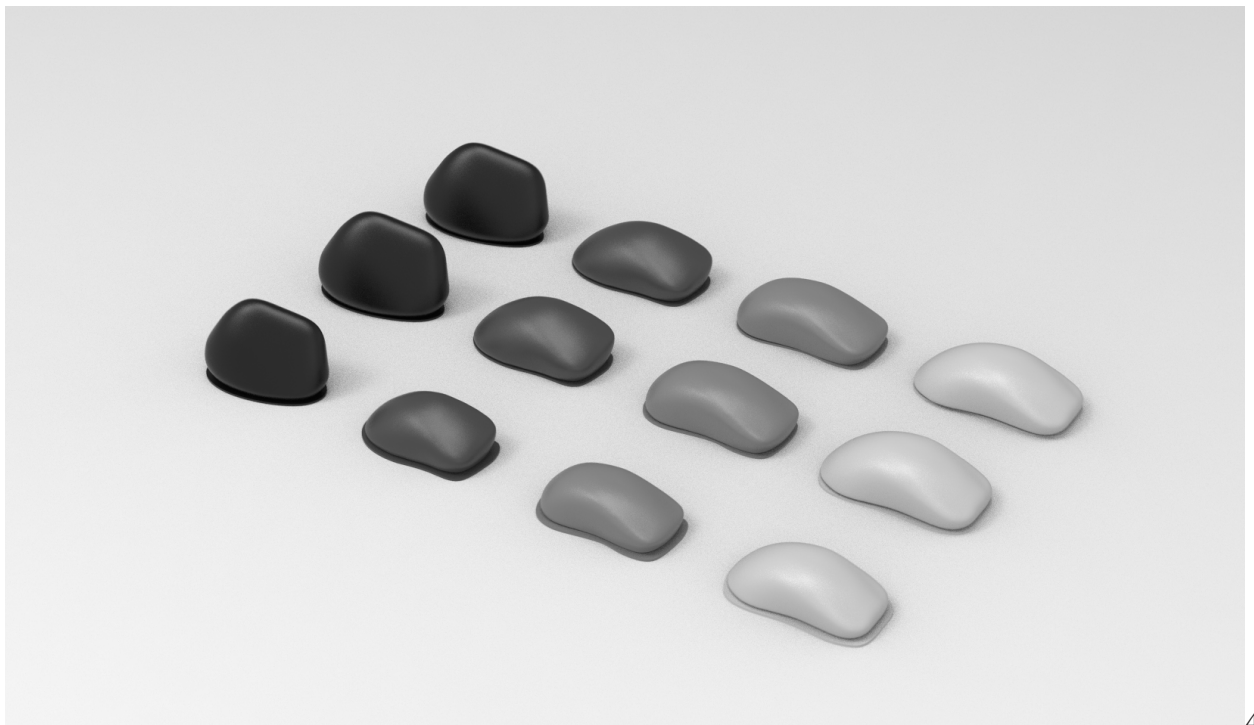


Image 5.14

12 base models



5.4.2 Molding

At the beginning, I tried to 3D scan the user's hand directly, but it did not seem to work. It is hard for the user to get a mouse holding position in the air and stay in the same position for minutes.

Thus, I decided to get the hand impression first, and then 3D scan the impression. I started to design the 12 base models and test different molding materials.

Image 5.15

Mouse 3D models



I bought several different popular mice on the market and went through many mouse review websites. I 3D scanned a few mice and downloaded some more mouse models online. By studying these mouse shapes, I created 12 base models of the mouse with three hand sizes and four grip styles.



Image 5.16

Molding materials tests

I tested a few molding materials including plasticine, polymer clay, paper clay, and finally decided to use thermoplastics. It is moldable when heated with hot water, easy to manipulate, and hardened at room temperature. It also capture detailed hand information.

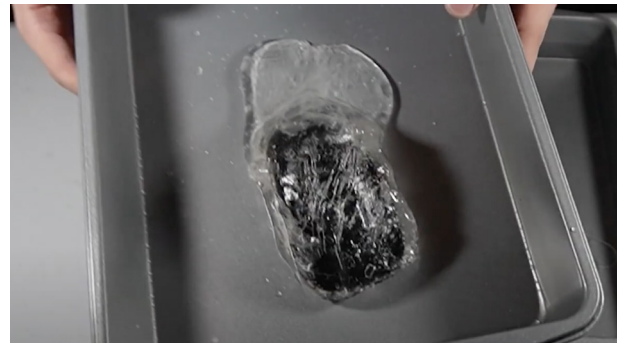


Image 5.17

Thermoplastic molding

We will send the mouse fitting kit to the users. The users will get their hand impressions using thermoplastic, which is moldable when heated, easy to manipulate, and hardened at room temperature. They will make the hand impressions based on their preference and then send them back to us.

5.4.3 Scanning

After the mouse fitting kit is received from the users, we will 3D scan all the parts and import the files into our software. It takes about three minutes to scan the mold.

Image 5.18

3D scanner



5.5 Generative Design

Through generative design, 3D models are created and optimized by computer software. Designers could use it for conception generation and iteration. With a pre-programmed algorithm, generative design can create a 3D model in a very short time.

5.5.1 Processing

With certain points and some support structure fixed, the algorithm could help generate 3D printable models directly from the scanned images, and the users could then select their preferred ones. However, due to the limited time, I did not have a chance to finish the algorithm. There are too many uncertain factors. Each base model requires an algorithm, and it requires a large amount of dataset of hand impressions. Instead, I manually make the 3D models and used generative design for weight reduction patterns.

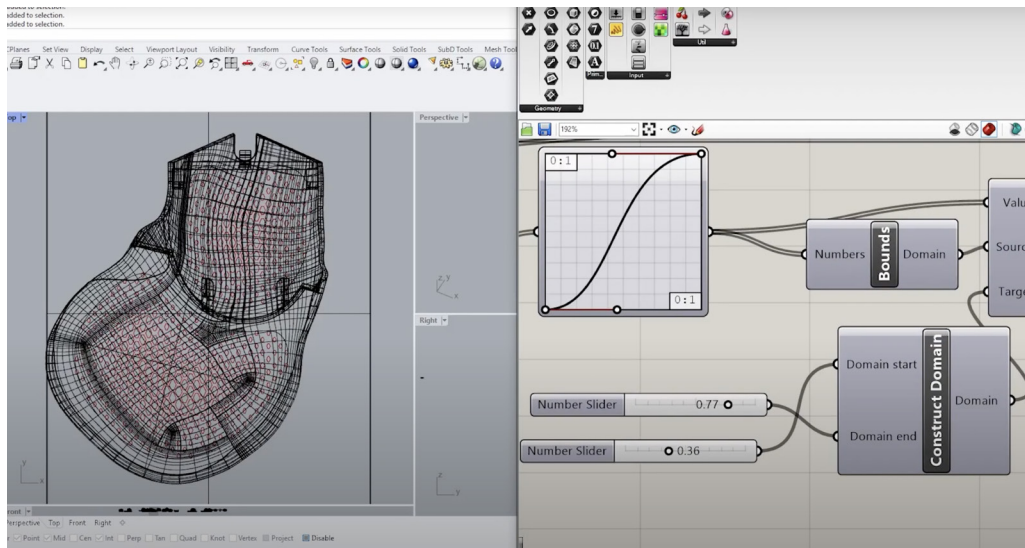


Image 5.19

Generative design for weight reduction patterns

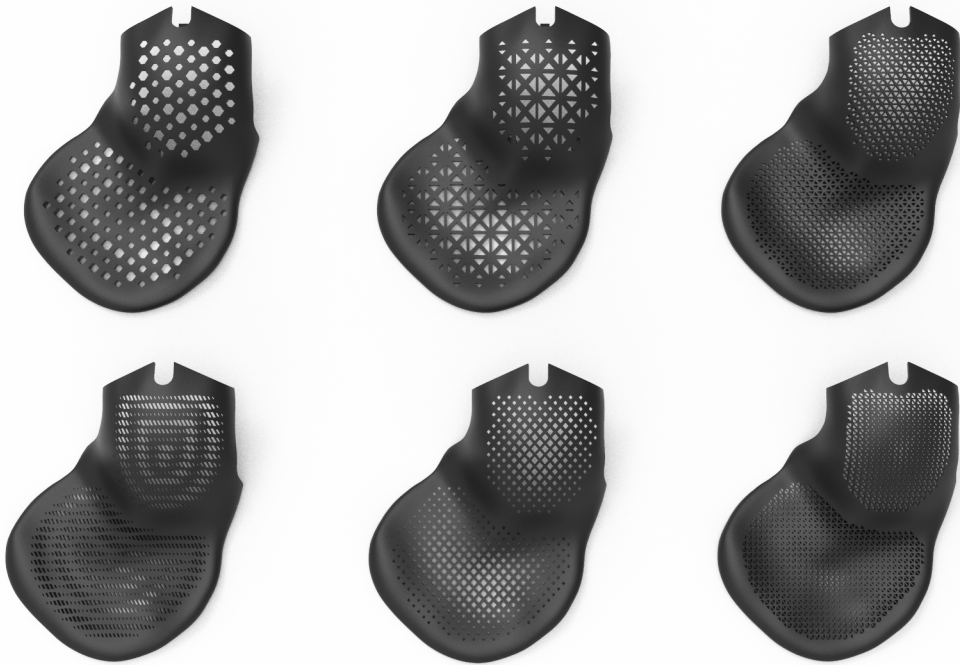


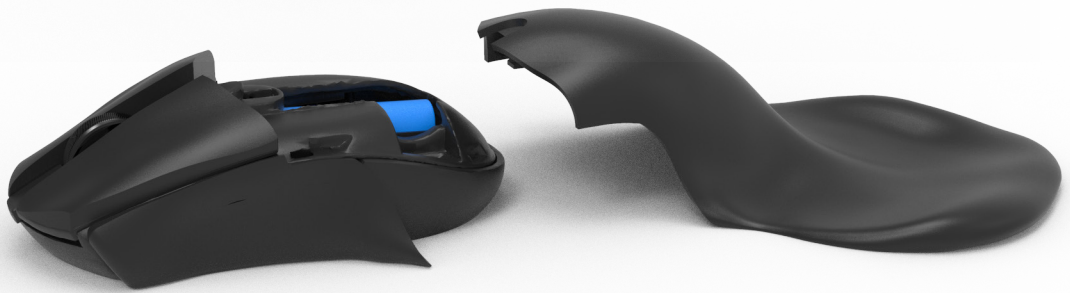
Image 5.20

Weight reduction patterns

Image 5.21

Customouse rendered images





5.6 Digital Fabrication

I am interested in trying the three different types of 3D printers: stereolithography (SLA), selective laser sintering (SLS), and fused deposition modeling (FDM), but due to the limited time, I only accessed to the FDM printers. For the materials, I tested PLA, LW-PLA, ABS, Nylon, and PETG. PLA and LW-PLA are the easiest to setup, and the outcome is durable and stable enough to use.

If I have more time, I would like to use CNC to machine a metal part or create a mold to make a carbon fiber part.

Image 5.22

3D printing
mouse shell



5.6.1 Finishing

Only the mouse shell and buttons are 3D printed. The inside structure and electronics are mass produced. For this Customouse project, I used Logitech G305 electronics to avoid welding and testing. I sanded all the 3D printed parts, used sandable primer to make the surface smoother, painted several layers of coatings, and assembled the shell with other components and electronics. The final mouse result is functional to use and fits my hand perfectly.



Image 5.23

Sanding

Image 5.24

Coating



Image 5.25

Coating



Image 5.26

Assembling



Image 5.27

Final result



6. Reflection



Image 6.1

Health Innovation Challenge Booth

I used this Customouse project to apply for the 2022 Holomon Health Innovation Challenge and 2022 Dempsey Startup Competition. After creating a business summary and talking to many judges with backgrounds in engineering and business, our team received many positive feedbacks. Through the competition, I believe the project proved the practicability and feasibility of the system customization process in real life.

“Looks like a great product with a large market potential.”

“I see MUCH potential in your business idea.”

“Really well thought out solution to a problem, unique to what is in the market.”



7. Conclusion

Most industrial design work is applied to physical products that are to be manufactured by mass production. The problem is that mass production promotes one size fits all.

As part of Industry 4.0, advances in technology, data, and analytics will increasingly give designers the ability to develop customized or bespoke products for a range of end-users. Specifically, the intersection of 3D surface scanning, generative design, and digital fabrication could trigger this growth.

The new approach to production - system customization provides a new way for industrial designers to embrace more bespoke design. The new design process with front-loaded design and customization utilizes data collection, generative design, and digital fabrication to make a better fit for the end-users. It is not always a good application for all products, but best for repetitive use tools

8. Bibliography

- [1] Kumar, V. et al., 2019. Ontologies for Industry 4.0. *The Knowledge Engineering Review*, 34(17).
- [2] Gorman, C., 2003. *The Industrial Design Reader*. New York: Allworth Press.
- [3] Campbell, I., Richard, J., Bahar, S. & Wormald, P., 2003. The potential for the bespoke industrial designer. *The Design Journal*, 6(3).
- [4] Gilmore, J. & Pine, B., 1997. The four faces of mass customization. *Harvard Business Review*, 75(1).
- [5] Lee, W. et al., 2015. *3D Scan to Product Design: Methods, Techniques, and Cases*. Lugano, s.n.
- [6] Robinette, K., Daanen, H. & Paquet, E., 1999. The CAESAR project: a 3D surface anthropometry survey. Ottawa, IEEE.
- [7] Black, S. & Eckert, C., 2009. Developing Considerate Design: Meeting Individual Fashion and Clothing Needs Within a Framework of Sustainability. *Handbook of Research in Mass Customization and Personalization*.
- [8] Helle, R. & Lemu, H., 2021. A case study on use of 3D scanning for reverse engineering and quality control. Chandigarh, *Materials Today Proceedigs* 45.
- [9] Lee, W. M. J. G. L. J. A. S. Y. G. R., 2019. Application of 3D scanning in design education. *DHM and Posturography*, pp. 721-732. Lobos, A., 2018. *Finding Balance in Generative Product Design*. Linkoping, Design Society.
- [10] Lobos, A., 2018. *Finding Balance in Generative Product Design*. Linkoping, Design Society.
- [11] Salta, S., Papavasileiou, N., Pylotis, K. & Katsaros, M., 2020. Adaptable emergency shelter: A case study in generative design and additive manufacturing in mass customization era. *Procedia Manufacturing*, Volume 44.
- [12] Di Nicolantonio, M., Rossi, E. & Stella, P., 2019. *Generative Design for Printable Mass Customization Jewelry Products*. s.l., Springer.
- [13] Lojanica, V., Colic-Damjanovic, V. & Jankovic, N., 2018. *Housing of the Future: Housing Design of the Fourth Industrial Revolution*. Rome, IEEE.
- [14] Han, S. et al., 2019. Recent advances in 3D printing: vascular network for tissue and organ regeneration. *Translational Research*, Volume 211.
- [15] Bionic Pets, 2022. *Dive Design*. [Online]
Available at: <https://www.divedesignco.com/work/bionic-pets> [Accessed 14 December 2021].
- [16] Sanders' Lab, 2022. Sanders' UW Lab. [Online]
Available at: <https://depts.washington.edu/jsweb/>
[Accessed 14 December 2021].
- [17] Mass Production, 2020, Investopedia. [Online]
Available at : <https://www.investopedia.com/terms/m/mass-production.asp#:~:text=Mass%20production%20is%20the%20manufacturing,large%20number%20of%20similar%20products>
- [18] Hu, S.J., 2013. Evolving Paradigms of Manufacturing: From Mass Production to Mass Customization and Personalization. *Procedia CIRP* 7, 3–8.
- [19] Sinclair, M., Campbell, R.I., Ariadi, Y., Evans, M.A., n.d. *AM-enabled Consumer Design* 9.

