Guideline to refine the product appearance based on analysis of the line shape in the two-dimensional views

by

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Abstract

According to the human perception, humans are more sensitive to the shapes of objects. For the product, the line shape represents the shape of the product in a two-dimensional view, and lines also work as the original and important elements of the visual world. Therefore, having a good outline contour is important for the product. Thus, this thesis is intended to study how to refine the line shape of the product in a two-dimensional view, which can make the appearance of product more reasonable and attractive.

In order to achieve this purpose, research is conducted to analyze the human perception of the lines, how to apply the produce semantics theory to line shape to making it more understandable, and also the need to analyze the human preference of the lines. Those methods are developed into the guideline to aid designers in analyzing the line shape and refine the appearance of a product in two-dimensional view. Finally a design example with design sketches, analysis process, and physical models is given to show the feasibility of the design guidelines.

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Introduction

1.1 Problem Statement

How does a human recognize the world? Humans use the sensory system to receive the stimuli from the outside and transport this information to our brain, and then our perception tells us what it is. How does the human recognize the product? Our sensory system also will catch the features of the product, and then we will understand what it is. Being attracted by the appearance of products is the basic natural behavior of the human brain. Much research and studies demonstrated that the sensory features of a product can affect the consumer's emotion and perception (Becker, Van Rompay, Schifferstein, & Galetzka, 2011; Ngo, Piueras-Fiszman, & Spence, 2012). Lines as a part of the sensory features of the product also can affect the customer's perception.

After the customer understands the product, they will produce the emotion towards the product and it will help them decide to buy this product or not. There are also many studies trying to find how lines affect human emotion and preference (Cheskin, 1967, 1981; Spence, 2012). Figuring out and analyzing the human perception and preferences for the different types of lines appearing in the product and what kind of lines can be counted as beautiful lines in the product, and then determining a method and guideline to help designers apply those rules into the product making product more understandable and attractive, is the main purpose of this thesis.

1.2 Need of Study

Bar and Neta (2006) said "A negative bias toward a visual object can be induced not only by the semantic meaning of that object, but also by low-level perceptual properties: even a

picture of something as harmless as a watch will be liked less if it has sharp-angled features than if it has curved features." This shows that the human preference and emotion is easily affected by the appearance of objects. And the object is formed by visual elements such as line, surface and volume, which means humans receive information through those visual elements. When seeing a product, people also would have different feelings and preferences regarding the shape of the product according to whether the shape is sharp, round, flat and so on. However, the shape of the product in the two dimensional world is formed by different types of lines. Whether a straight line, concave line, or convex line, each line causes a different influence on human preference and emotion. Having an attractive look and leaving a good first impression to customers is important for the product. Based on the process of design, the design of the product usually starts with the sketches, which are made of lines. How to come up with a guideline which starts with analysis of lines based on some questions, like how people recognize the line (human perception), what kind of line is beautiful (product semantics), and human preference of lines to make products more attractive, is what we need to study in this thesis.

1.3 Objectives of Study

The objective of this study is to provide a method for designers to analyze the line shapes in products and improve the product appearance in a two-dimensional view. In order to achieve this goal, the following is a summary of what this research will focus on:

- Identify how people's sensory system and perception works and understand how users recognize the products and the lines. Figure out the line features in user views.
- Develop design guidelines based on the relationship between human perception, product semantics and human preference to improve the line shapes in products.
- Execute the design implementation to illustrate the findings of the design

principles developed in the thesis.

1.4 Definition of Terms

Concave line- Rounded and hollowed inward line which is like a bowl shape or smile-like shape (Merriam-Webster Dictionary, 2004).

Convex line- Rounded and curved outward line which is like a frown-like shape (Merriam-Webster Dictionary, 2004).

Fibonacci Spiral- A curve line which is created by drawing the 1/4 circular line which connects the opposite corners of the squares (Tiner, 2004).

Golden ratio- A number whose value is: $\varphi = \frac{1+\sqrt{5}}{2} = 1.61803398887$ .... and the calculation equation is $\frac{a+b}{a} = \frac{a}{b}$. It also has many other names like the Golden ratio, Golden number, Golden proportion, Golden cut and etc (Tiner, 2004).

Human preference- The consequence of the understanding of objects, an emotion helping people figure out if they like or dislike the objects and making decisions. Having the positive side and negative side (Palmer, Schloss, & Sammartino, 2013).

Line- The object which consists of numbers of points and only has one direction. It doesn't have width and depth in the mathematics area, but in the design area, it has many elements such as weight, length, texture and so on.

Perception- The process of dealing with the sensory signals coming from the sensory system and producing the understanding of the object which the sensory system detects (Bernstein, 2011).

Product contour- The outline or outer edge of the product (Merriam-Webster Dictionary, 2004).

Product semantics- A theory of product design whose main goal is making the product more understandable (Krippendorff, 1989).

Straight line- A line without any bend and curves, the shortest distance between two points (Merriam-Webster Dictionary 2004).

Sensory system- A system, which contains the vision system, hearing system, taste system, smell system and touch system, belongs to human beings, gathers the energy from outside and reflects those energies as stimuli to human brains (Bernstein, 2011).

1.5 Assumptions

This study includes many assumptions detailed as follows:

First, the human sensory system includes many sensors such as vision system, hearing system, taste system, smell system and touch system. When humans receive information from the outside, those sensory systems work together and humans can receive stimuli such as sound, light, heat and pressure. Here we presume when humans see the line drawings of products in a two-dimensional view, only the vision system works because there is no sound, heat or other stimuli in the two-dimensional world.

Second, human preferences indicate the humans' like or dislike of products. When seeing a product, customers can tell if they like it or not, which will influence the customer to buy the product or not. So we can assume that the product appearance can influence the human preference.

Third, the main purpose of product semantics is helping people understand the product more easily. Once people understand the product, there are two attitudes they may produce: one is positive and the other is negative. Based on the method of product semantics which can improve the user understanding of product and the principle of golden ratio which recognizes the

form of beauty, we assume the lines applied to the method of product semantics and the Golden ratio is beautiful and can let people produce positive attitudes.

1.6 Scope and Limitations

This study focuses on analyzing the lines of products based on human perception, product semantic and human preference, and then comes up with a guideline to improve the product appearance. However, the guidelines researched in this study are not limited to the lines of products, so that the designer also can use this method to analyze the surface of the product. The reason why the primary research and analysis conducted for this thesis is limited to the lines of product is because the line shape in the product represents the appearance of a product in the two-dimensional world and it also follows the processing of sketch design.

The main features of lines covered in this study are physical line features, such as the line shape and line weight, and the psychological line features, such as the meaning of the line and symbol of lines, instead of the color of lines because based on the human perception, humans are more sensitive to the shape of items than the color. So compared with the color, shape is more important for designers to analyze.

1.7 Procedures of Study and Methods

The following procedures are used to conduct the study:

Step 1. Literature Review

- Research how humans recognize items and lines.
- Summarize the definition of product semantics and its the methods.
- Summarize what kinds of lines are beautiful and what the golden ratio is.
- Research the human preference about the lines.
- Build connections between human perception, product semantics and human

preference.

Step 2. Analyze the lines of a product

- Analysis how to transfer a three-dimensional product into line drawings in a two-dimensional view.
- Analyze the line features in the line drawings.

Step 3. Develop a set of guidelines for product design.

- Apply the findings of lines to the connections between human perception, product semantics and human preference.

Step 4. Apply the design guidelines to a sample of design work

Step 5. Discuss conclusions

1.8 Summary

Many issues relevant to the design guidelines of redesigning the appearance of the product based on two-dimensional line shapes, such as how the human recognizes the lines, the human preference of the different lines, and how to make the outline of the product more understandable based on produce semantics, has been documented. In order to successfully analyze the line shapes and develop a guideline to improve the appearance of the product, the literature review emphasizes the importance of building connections among human perception of lines, product semantics of outlines in products and human preference of lines.

Chapter Two

Literature Review

2.1 Human Preference of The Product

2.1.1 How Humans Recognize The World

2.1.1.1 Sensory System and Perception

How do we recognize the world? For humans, we have two important systems to handle the outside information to let us see the world: our sensory system and perception system. In the book *Essentials of Psychology*, it shows what the sensory system is:

> So for the sensory system, the sense is a bridge that translates or transfers the outside information to the nervous system. Our senses gather information about the world by detecting various forms of energy, such as sound, light, heat, and physical pressure. We can call all those energies like sound, light, heat and pressure as the stimuli. Humans have a whole sensory system including vision system, hearing system, taste system, smell system and touch system (Bernstein, 2011).

Eyes help us see the form of items like shape, color and size: ears helps us hear the sounds; the mouth help us taste the flavor of things; the nose helps us smell and the hands help us feel the items. The whole sensory system helps us to understand this world.

And how does the sensory system work? The process of sensation is divided into many steps. As the book *Essentials of Psychology* said: The first step, called "accessory structures," can modify the stimuli that are received from the surroundings. The second step is " transduction," which has neutral receptors and can change those incoming stimuli, or we can call it as energy to neural activity. From this step, we can recognize those stimuli and know which

category it belongs to, like sound, light, or heat and so on. The third step is our sensory nerves collects this information and transports that information to our brain. Then this information goes through the thalamus to the cerebral cortex (Bernstein, 2011). This is the whole process through which our sensory system receives those stimuli and transfers it to another form that our brain can understand.

After our brain receives the information it can understand, it begins another activity which tries to figure out what the meanings of this information, called "perception".

> Perception is the process of using information and your understandings of the world so that sensations become meaningful experience. Perception is so quick and familiar that it is difficult to appreciate the process that allow you to turn sensory signals into your personal experience of reality (Bernstein, 2011).

Because different people create different understandings based on different knowledge, they can produce different perceptions about the same item.

Perception is divided into two different parts when we recognize items. The first part is called bottom-up processing, and the second part is top-down processing (Bernstein, 2011). When our sensory system transports information of our surroundings to our brain, certain cells will receive this information and recognize those stimuli by certain features. Some studies show that those features can be the lines, edges, corners and stimuli that have space orientations and even colors and motions (Beatty, 1995; Cowey, 1994; Hubel & Wiesel, 1979; Treisman, 1999). Bernstein (2011) gives a description of the bottom-up processing: "Raw sensations from the eye or the ear are analyzed into basic features, such as edges, color, or movement; these features are then recombined at higher brain centers, where they are compared with stored information about objects or sounds." In the process of maturation, people's sensory system keeps receiving

information from the surroundings and sets up a database to help people recognize items. Then when the sensory system transports those features of stimuli to our brain, our brain will search in that database, compare those features and then tell us what it is; such as when you see a cat, our sensory system will transport the cat shape, meow sounds, and special behavior as the key features of stimuli to the brain, and then the brain will search for those features in the database and then tell you it is a cat.

The book *Essentials of Psychology* also gives the description of the top-down processing like this: "knowledge of the world and experience in perceiving allow people to make inferences about the identity of stimuli, even when the quality of raw sensory information is low" (Bernstein, 2011). Sometimes, our sensory systems will be influenced by the many interference factors in surroundings, such as you can't see a distinct color in the dark, can't hear clearly in a noisy environment and so on. But once our brain receives those vague features of stimuli, it can still tell you what it is because our brain will handle those features with our cognition and knowledge. The book *Essentials of Psychcology* called this mechanism "schemas, mental representation of what we know and expect the world" (Bernstein, 2011). Schemas help our brain detect the information received from the sensory system to create new recognition. An abbreviation of a word is a simple example of that; once you type in text to respond to someone, usually you won't type all words fully to make a sentence. "CU" means goodbye, "B4" means before and so on; those words can help you respond quickly and they also represent the correct information even though they are in a "wrong" format because our brain uses preexisting knowledge and provides the correct information.

Different from the bottom-up processing, top-down processing has some factors that can influence the schemas: expectancy and the motivation. When people stay in the specified surroundings, they will produce an anticipation which can influence the perception the brain produces. Bernstein (2011) gave a better description of the expectancy, claiming "the expectancy is shaped by the context in which a stimulus occurs" (Bernstein, 2011). For example, if someone lives nearby the fire department, he won't feel it strange when he hears the fire alarm from the fire truck, because his perception tells him it is normal, but once the people who live far away from the fire department hear fire alarm at home, his perception will tell him something is happening. At that point, the expectancies influence the human perception. Motivation is another factor that can influence perception. When people have a strong motivation to get something or achieve some goals, this motivation will force the brain to link with the surroundings and search for similar things. Bernstein (2011) gave an example: when a hungry person may misunderstand the sign for Burger's Body Shop because his motivation forces him to focus on the food information and therefore the sign indicates a place to get food to the hungry people. People then

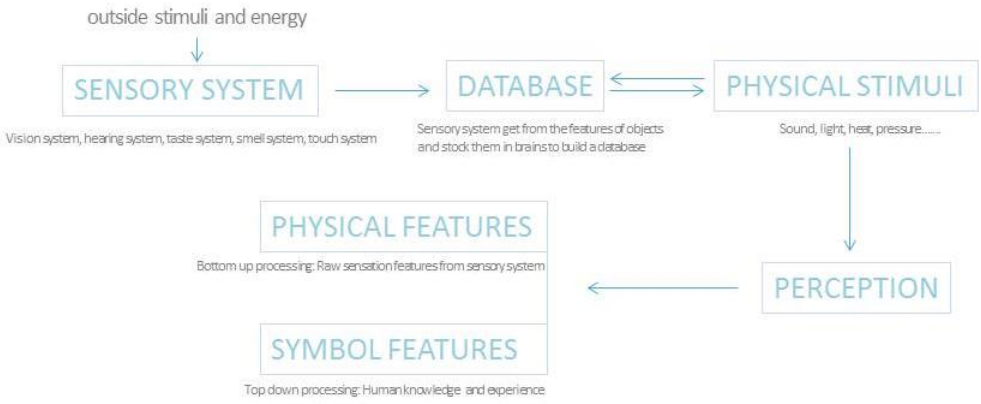


Figure 1 The process of sensory system and perception receiving stimuli

become to sensitive to that information and link to his perception regarding food.

The picture (see Figure 1) shows the main process of the human sensory system and human perception.

2.1.1.2 The Method of Recognizing The World

When you start to understand an item, there are two processes. In the book *Essentials of Psychology*, Bernstein (2011) said: " Psychologists distinguish between sensation (the stimulus message coming from the senses) and perception (the process of giving meaning to that message)." Bernstein (2011) also gave an example to explain how people understand there is a cat. First our eyes receive the signal and picture from environment, like the shape and color of the cat, and then transport this information to the brain. Based on our understanding and knowledge, we get the result there is a cat, so when our sensory system and perception work together, human can detect items and the world. Sensory systems "watch" the world, and perceptions tell you what the world is. We can describe the sensory system and perception as the method for people to understand all that is in the world.

2.1.2 Product Semantics and Human Preference

2.1.2.1 Product Semantics

When you go into a furniture store and want to buy a chair, after viewing hundreds of chairs, you pick up one and say you like to buy it. Do you know why you like it and want to buy it and what factors influenced you to choose that chair? Krippendorff (1989) pointed out that people like to stay with the things that can be familiar so people can handle and arrange those things with a feeling of comfort. That's why people may not take a task chair which one hundred percent fits the ergonomics rules as the first choice when they want to buy a chair. A product with full functions may still not be attractive enough for customers to buy it. People can live with

the furniture that has malfunctions as long as they like it. For example, most of the computers which belong to different brands or the same brands have the same functions, but the customers only choose what they like to play with even if another one has better functions. People choose whatever they like based on what they need. The motivation of choosing a product is not rational and it also can't be determined by the object criteria, but it's derived from the individual understanding of the customers (Krippendorff, 1989). The “motivation” makes people produce the intention of getting a product to satisfy their needs, but the “individual understanding” helps them make the decision of which product they like. Compared with the ultimate function of the product, the users prefer the product that can be easily identified and also can be understood easily to operate it. So these realizations create a question: how can a designer make a product understandable?

If the sensory system and perception is the method for human understanding the world and products, the product semantics are the link between the user and product. The main goal for product semantics is a study of any factors that can help people understand the product better.

2.1.2.2 Human Preference

We have to make decisions for many things surrounding us. Once our sensory system receives the stimuli from the outside, our perception tells us what it is. Our brain already starts to make decisions for us, such as whether to wear this yellow T-shirt, but not that green T-shirt, or whether to buy that chair with a square seat panel and not that rounded chair. Our brain helps us distinguish which things we like or dislike. Those considerations based on our aesthetics are deeply involved in our mental life, and they also reflect and explain our preferences (Palmer, Schloss, & Sammartino, 2013). Once humans begin to produce an understanding of subjects, what is the next step that may happen? They can say they like this subject or dislike that subject.

It is a consequence of the understanding of subjects. Those human preferences help people to make a decision.

The human preference can be influenced by many factors, like objective factors and subjective factors. Objective factors come from natural human characteristics, like emotions, which can be affected by the feelings of the emotion. Negative emotions like threat, loss, risk and positive emotions like safe and comfortable can cause different results to human preference. Tversky and Kahneman (1981) points out compared with the possibility of equivalent gain, the threatening of loss has a larger influence on the decision we make. When humans feel negative emotions like threats from one thing, they may prefer the other thing which can make them feel safer and that they are more familiar with. In that case, humans have the same behavior and the same decision because they have the same preference of our human nature, forcing us to stay away from the "threatening" feelings and get closer to the "safe" feelings.

Other factors that can influence the human preference include the subjective factors that are caused by our perceptions, which can be changed by our experience, knowledge and so on. Different people have different behaviors and decisions because they have different experiences and knowledge that can produce different preferences.

2.1.3 The relationship among perception, product semantics and human preference

After discussing what perception, product semantics and human preference are, let us discuss the relationship among them to figure out what kind of lines people like and why.

As discussed above, the perception is the method for human to understanding the world and its subjects. So when a customer sees the product, their brain will tell the customer what that is and that item is used for, and many other pieces of information, and all this information is based on the human perception systems.

When people see the product and understand what it is, there will be a result reflecting to users from the product. Users will produce an attitude towards the products and their brains will tell them if they like this product, or dislike it, which influences the human behavior, or human decision to buy this product or not. That's why you can say you prefer this product and don't like that product. Human perception helps you receive information about the products and the human preference helps you decide if it is what you want.

For designing the product itself, there is also a scientific method called product semantics, and its main goal is to help the designer design an "understandable" product. A product that follows the semantics method can help customers understand it easier. So product semantics can also influence the human decision of the products.

The picture below (See Figure 2) can show the detailed relationship between human perception, product semantics and human preference. It works as a circle, which influences the user to understand and choose the product.

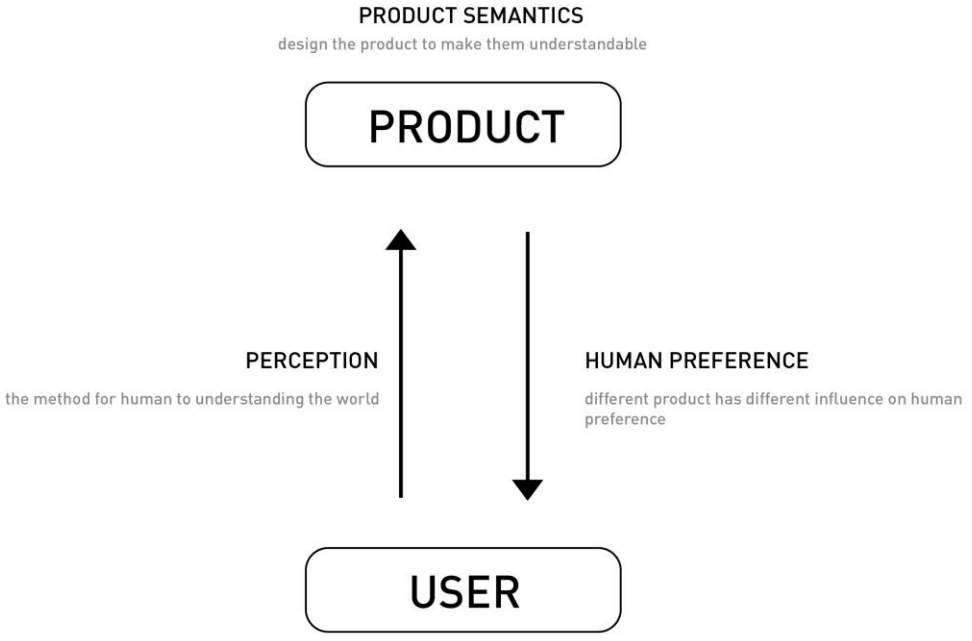


Figure 2 The relationship among product semantics, perception and human preference

2.2 Cognition of Lines

2.2.1 What Are Lines and the Human Perception of Lines?

The human started to know lines a long time ago, but what are lines? What is the human perception of lines?

There are hundreds of definitions of lines. Starting at the ancient times, people kept trying to find a proper way to describe the concept of a line. In the book *Les quinze livres des éléments géométriques d'Euclide Megarien*, it gave a description of the line:

> The [straight or curved] line is the first species of quantity, which has only one dimension, namely length, without any width nor depth, and is nothing else than the flow or run of the point which […] will leave from its imaginary moving some vestige length, exempt of any width. […] The straight line is that which is equally extended between its points.

In Mathematics, they use lines or straight lines to represent the object with just one direction, which means it doesn't have width and depth, just a length. If we extend a number of points in one direction, we can get one line.

But in the physical world, a line without any width is an abstract object. Humans can't detect it through the eyes because our sensory system, especially our eyes, cannot detect the "invisible" subject. Therefore, the width of a line is required for visible area. "Graphically, lines exist in many weights; the thickness and texture as well as the path of the mark determine its visual presence" (Lupton & Phillips, 2008). When we give thickness and texture to a line, we also give the aesthetic meaning and human preference to it.

In the design area, the width of a line is described as line weight. In Figure 3, all lines are the same in the x-axis. They all follow the same direction in the x-axis with the same length, but in the y-axis, they have different thicknesses.

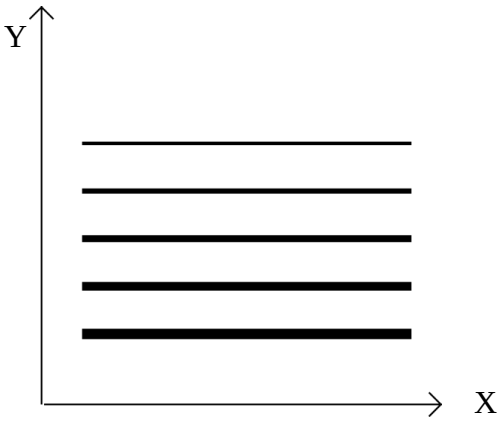


Figure 3 Line weight

It even shows up in many design software programs (see Figure 4). Humans use lines with different weights to satisfy their aesthetic demand. In the different software programs, they use different words to describe the line weight, such as Stroke weight in *Adobe Illustrator*, Shape outline weight in PowerPoint, and Size in Paint.

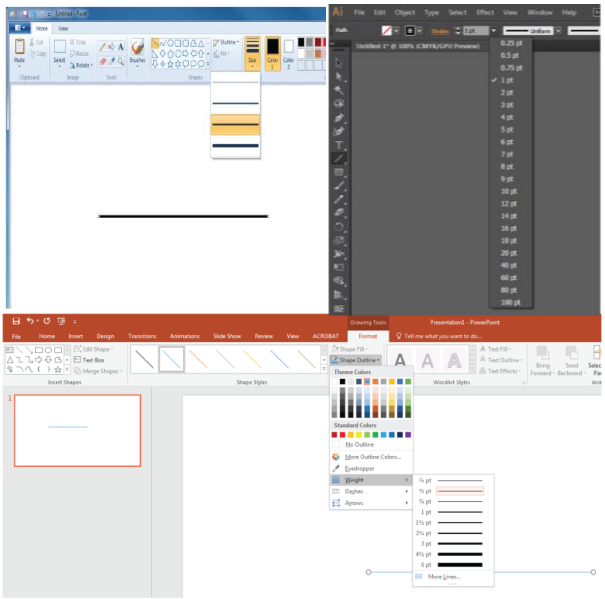


Figure 4 Line weight in different software

When humans see the lines in the real world, our perception will handle this information with our cognition and tell us what it is and the features of lines. Our sensory system can also detect many features of the lines as stimuli and transport this information to our brain, so we can know the features of lines, such as the shape of lines, the line weight and so on.

Because of the three basic properties of line, there are three different shapes of lines in our daily lives: concave line, straight line and convex line.

In Mathematics, we can put a line into the Coordinate system to judge which category it belongs to. According to the trend of line weight direction in the Y axis, we can tell if it is a concave line, a convex line, or a straight line.

From Figure 5, we can see the weight direction of convex line trends to Y-axis positive direction and the weight direction of concave line trends to Y-axis negative direction. Meanwhile, the weight direction of straight line does not have trends.

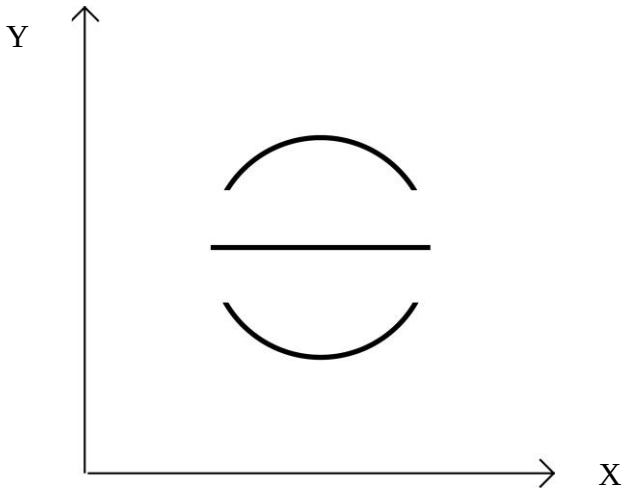


Figure 5 The trend of line weight

The Merriam-Webster dictionary also gives those three lines different definitions. “Concave” is featured as rounded and hollowed inward; it looks like a bowl from the inside view. Concave line is often applied as a main feature to parts of architecture such as arch

bridges, building entrances, and even the whole building because of the concave line's beautiful look and stable features (See Figure 6).

Figure 6 Examples of architecture

Different from the "concave", convex is defined as rounded and curved outward, which makes it looks like a part of a circle. According to the shape of the concave and convex and combined with the knowledge and social association from the outside, people give them different implied meanings. A concave line is similar to a smile-like line and convex is a frown-like line, which influences the human emotion and preference about them.

The straight line is a line without any bends or curves. And it also represents the shortest distance between two points.

So when humans see the lines, our sensory systems catch the main features of lines such as the line weights and line shapes, and send those main features as stimuli to our brain. Then our brain receives the information and perception of those lines, giving related imaginings of those lines, like this is a smile concave line and this is a frown convex line. Once this happens, we start having a basic understanding of lines.

Also, when processing features accumulate while growing, our sensory system will store those "features" in our brain database and combine that with our perception. We associate links or special meaning given to the lines, such as smile to concave lines or frown to convex lines. And those links are different among people depending on the different databases each person has in his or her brain. However, there is also some common cognition shared with each other because of the same education or same cognition of the same items.

After we have a basic understanding of lines, we begin to try to use many ways to represent and calculate the lines. When we convert a product from a three-dimensional view to a two-dimensional view, we call those product line shapes product contours.

In product design, every product is built by different points, lines, and planes. These elements represent the product in the two-dimensional world and three-dimensional world. When humans contact the product for the first time, according to the perception process, their eyes will transfer the product from a three-dimensional object in reality to a two-dimensional image and send the image to the human brain. Eventually, they will "see" an image of the product. Product contour, as the part of the image, is also received by the human brain. What is a contour? According to the Merriam-Webster Dictionary (2004), a contour is " the outline or outer edge of something", and it also represents the line of the outline. Extending this meaning to a product contour, it can be understood as the outline of the product (See Figure 7).

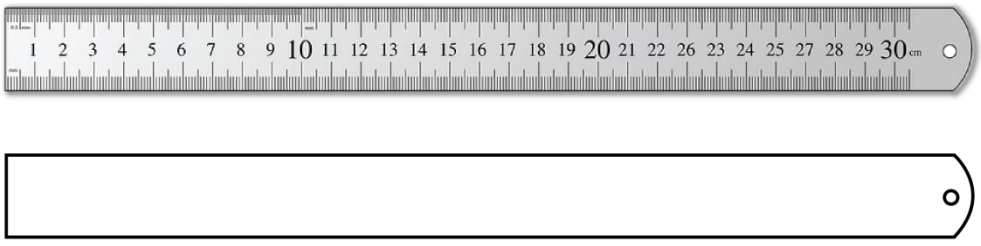


Figure 7 Example of product contour

Because a product contour is an important part to help user perceive the product, there is a question here. How to convey a three-dimensional product into the two-dimensional drawing? There is already a scientific method, which can describe a product by lines, called three view drawings or engineering drawings. By using this method, a product can be described by lines in many views: front views, top view and left views and so on. Once an object and three-dimensional product can be represented in the drawing, we can use the subjective method to measure it and estimate it.

Many design software programs can provide a similar function, which can output three view drawings according to the three-dimensional model. For example, in Solidworks, designers can build a three-dimensional model into that software, and then use a function to output a two-dimensional engineering drawing.

2.2.2 What Is a Beautiful Line, Product Semantics of Lines?

2.2.2.1 Methods of Product Semantics

The main goal of product semantics is making a product understandable, like building a bridge between the product and users. Product semantics is a new challenge of the design because it requires the designers to think about the meanings of the objects. Product semantics recognized that the humans do not respond to the physical qualities of objects such as the functions, the materials, but are interested in what the objects mean to them. The meanings of the objects look more important for them when they decide which object they like (Krippendorff, 1989; Evans & Sommerville, 2007).

Evans and Sommerville (2007) came up with some key concepts of the product semantics: First one is “ making sense”. When we see an object, we will automatically ask

questions in our heart: why it is there, what we can do with it, what its name is and so on. Once we get a coherent explanation of all the questions, we can say this object makes sense.

The second key concept is “meanings”. “The meaning of something is the set of contexts in which we are able to imagine it to make sense to us” (Evans & Sommerville, 2007). Knowing the meanings of an object can help humans understand it better.

The third one is “categories”. It requires users give an object a situation. When we see a kitchen table, we can easily know what is it and know where we can put it because we give this table a category like “table in kitchen”. We can easily compare it with another table with the same category in our brain.

The fourth one is “interface”. A good product needs the user to interface with it. It requires the participation of the users. And the fifth concept is “ affordances”. In the view of Evans and Sommerville, if the affordance of an object corresponds with the functions it has, this object will work efficiently and also will be easier to use.

The sixth and seventh key concept of product semantic is “motivation” and “Cognitive Models”. Motivation is divided into two parts: extrinsic motivation, such as seeking the opportunity to solve problems or achieve some goals, and intrinsic motivation, or meanings of the mental feelings the product is involved in. The cognitive models are the human cognition of the objects.

Krippendorff (1989) also came up with three methods of product semantics: descriptive, anticipatory and creative. Descriptive means giving the object a description. It can include the key words “make sense, meaning, affordance, and motivation” in the theory from Evans and Sommerville because both of them are talking about the basic description of one object. The main purpose of them is figure out what this object is, what it can do and other basic problems.

Anticipatory means the images that exist in human brains. Once humans know what they want and give a description of the object they want, they will start to imagine and build a picture in their brain based on their understanding, their knowledge or their experience. This method can include the key words: “category, interface and cognitive models” because all of those are based on human understanding.

Creativity is the third method of his theory. It requires designers to apply some creativity to design the product to avoid making users feel “bored” when using the product.

2.2.2.2 What Is a Beautiful Line Based on Human Understanding

After knowing the basic understanding of lines, how does a human judge if this line is beautiful or not? What kind of lines can be counted beautiful based on the human understanding? Following the main purpose of the product semantics (making the product more understandable), finding a standard to judge if a line is beautiful based on human understanding is important.

In the mathematical area, there is an interesting number called the Golden number whose value is: $\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887$ .... The calculation equation is $\frac{a+b}{a} = \frac{a}{b}$. (See Figure 8)

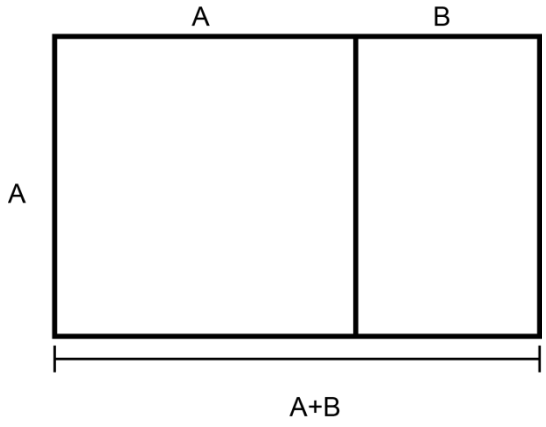


Figure 8 The Golden ratio

And it also has other names like the Golden ratio, Golden proportion, Golden cut, Golden ratio and so on. This golden number also exists in many areas such as Mathematics, Art, Geometry, Design, Theology and even Life.

2.2.2.2.1 The Beauty of the Golden Ratio in Natural Area

Using the golden number can create many beautiful shapes. Many resources claim that the Golden ratio works as the essential part of the beauty in nature. When we use concave lines to connect each square, we can obtain a perfect spiral. This spiral can be found in natural objects.

Jean (1992) pointed out a special number sequence (1,2,3,5,8…), defined as the Fibonacci numbers in mathematic area, can be observed in over 92% of the Plant Phyllotaxis. The Fibonacci number is an important representation of the Golden ratio. If making fractions of pairs of Fibonacci number, then we can get the results 1.000, 2.000, 1.500, 1.667, 1.600, 1.625,1.615…The result of those fractions will get closer and closer to the golden number (1.618). And the famous Fibonacci spiral (the golden spiral) (See Figure 9) is also created by drawing 1/4 circle lines which connect the opposite corners of the squares.

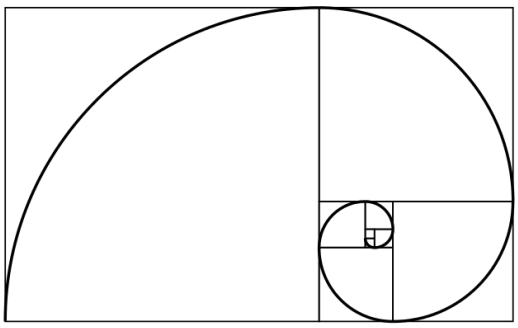


Figure 9 Fibonacci spiral

Brousseau (1968) collected thousands of pine cones from 12 different kinds of pine trees which were located in different areas and analyzed the golden proportion in them. Only 1.7% of them did not keep the golden proportion, which means Golden ratio patterns exist frequently in

pinecones. The Golden ratio not only just can be found in pinecones, but it also can be found in other natural objects.

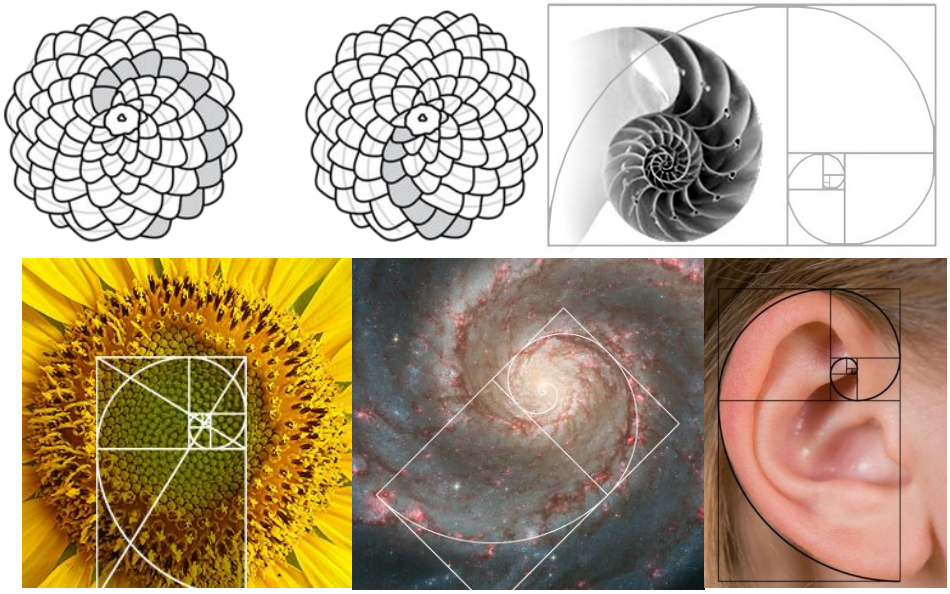


Figure 10 Examples of Golden spiral in nature

"The shell of the chambered nautilus, the curl of the horns of some animals, the spiral of an orb weaver spider web, and the arrangement t of the inner ear of humans all have the spiral shape. It is found as the whirl on the surface of pineapples and in the arrangement of stars in distant galaxies" (Tiner, 2004, p. 81) (See Figure 10).

2.2.2.2.2 The Beauty of the Golden Ratio in the Human Craftable Area

Over the centuries, the Golden ratio has influenced many areas, such as Architecture, Art, Design, and Mathematics, as an essential part of beauty perception. Many great artists create items according to the principle of the Golden ratio. For instance, the structure of the Parthenon at the Acropolis of Athens is influenced by the golden structure (See Figure 11).

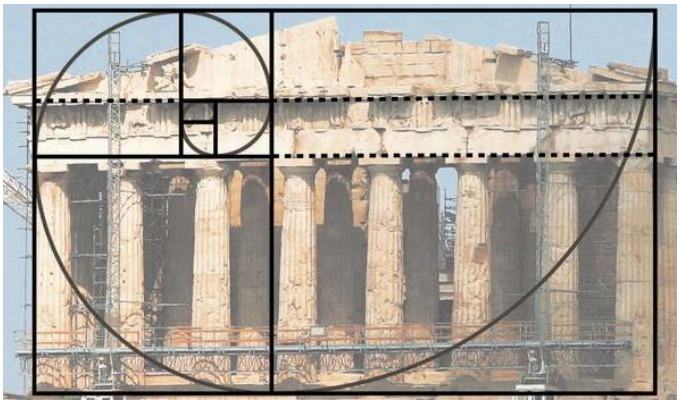


Figure 11 Golden spiral in Parthenon

Famous artist Leonardo da Vinci also has drawn the *Vitruvian Man* to present the perfect human proportion he thought according to the Golden ratio. And the Golden ratio also can be found in many famous paintings such as *Mona Lisa, The Last Supper* and so on. The key dimensions of that painting, such as the room, the table and ornamental shields, all follow the Golden ratio (See Figure 12).

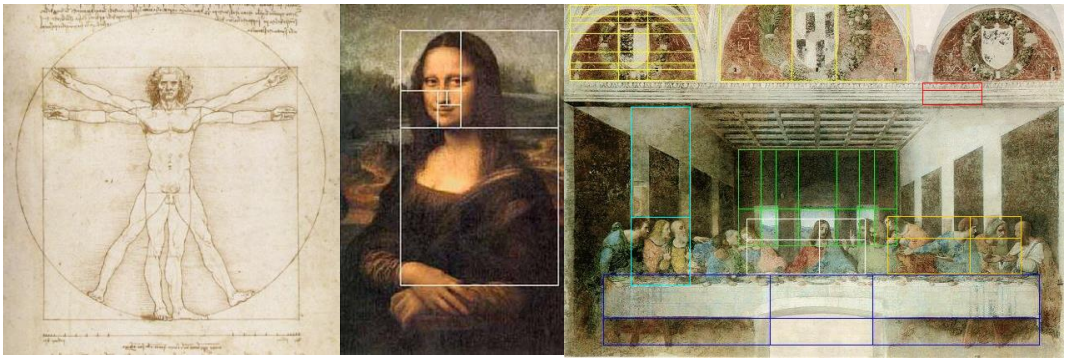


Figure 12 Golden spiral in art works

And also much evidence shows that the Golden ratio influences designers' thinking. Designers decide the size of a postcard, business card, the proportion of typography, general layout in graphic design and web design and even the shape of logo design (See Figure 13) according to the Golden ratio.

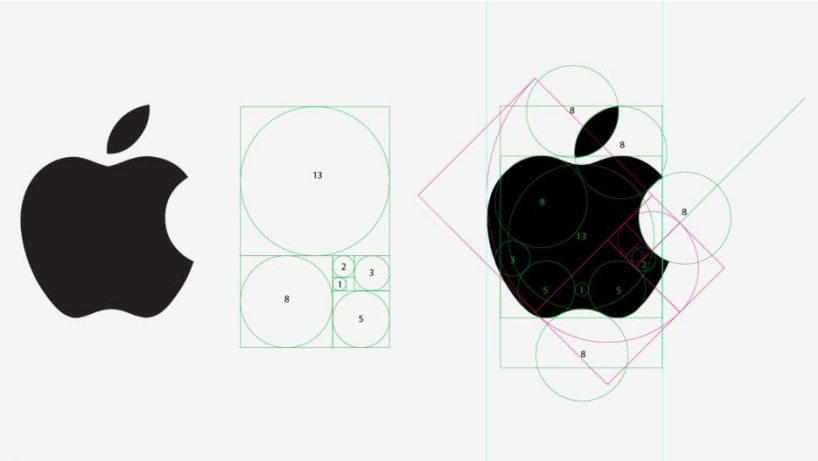


Figure 13 The Golden ratio in logo design

In the book *The power of limits: Proportional harmonies in nature, art and architecture*, Doczi (1981) gave the description of the power of the Golden ratio:

> The power of the Golden section to create harmony arises from its unique capacity to unite the different parts of a whole so that each preserves its own identity, and yet blends into the greater pattern of a single whole…It gave rise to their belief in the mystical power of numbers. It also led to their endeavors to realize the harmonies of such proportions in the patterns of daily life, thereby elevating life to an art.

Doczi (1981) also points out that, through analysis and calculation, the Golden ratio exists in different flowers, fish body shapes, butterfly's wings, the shape of galaxies and even human being bodies. Even the design of the keys on the piano also follows the Golden ratio rules. He figured out the reason why the fish bodyline looks smooth and helps fish swim fast in water; the sunflower looks attractive, the sound of the 2:3 proportions, which is called "diapenta", sounds impressive and harmonious. It is because all their structures has a Golden ratio proportions.

Also many studies (Fechner, 1876; Fechner, 1997; Vico-Prieto, 2016; Witmer, 1894) show that the shapes which follow the Golden ratio can attract people's attention. Human shows a preference to the golden ratio. Fechner (1876) conducted an experiment about the Golden ratio. He set up ten rectangles with different proportion of width to length and put those white rectangles on the same size black tables to reduce experiment deviation. Then he invited numerous observers and let them choose the preferable rectangle-which rectangle shape is the best and which one is the worst. The result showed that the best rectangle shape chosen by most people had the ratio of 0.62, which is close to the Golden ratio (0.618). Witmer (1894) came out with a similar experimental result by replicating the same experiment. This time the most preferable rectangle had 1:1.65 width to length ratio, which also is close to the Golden ratio.

From those experimental results, it is not hard to tell that humans prefer the rectangle shape, which is close to the Golden ratio, but does this phenomenon appear in another area? Also, there were some experiments and studies, described here, that show that the golden ratio influences human preference in another area too. Vico-Prieto et al., (2016) conducted an experiment about the golden ratio in Mondrian Paintings. He modified the black and white proportion in Mondrian Paintings to fit the Golden ratio, 1/6 and 1/2 proportions. Also, the researcher invited many participants to choose the preferred painting. The result showed the preference of the golden ration painting is for the 1/6 proportion painting, but not the 1/2 one.

2.3 Human Preference of Lines of Products

2.3.1 The Importance of Lines in Product Semantics

Eyes as a main sensor for human to collect information are also related to product design.

Some research shows that visual appearance of of the product will affect the choice and product evaluation from the customers (Creusen, & Schoormans, 2005). When humans see a

displayed product, usually the first impression is important. The consumers' first impression is determined by the design of the product, and the appearance and design also build a bridge between consumer and product to communicate the product advantages (Berkowitz, 1987; Bloch, 1995; Pilditch, 1976). A good product with a good appearance can increase the interests of the customer, and it is also a competitive tool and advertisement for many companies (Dumaine, 1991; Nussbaum, 1993; Smith, 1994). Creusen and Schoormans (2005) claimed the appearance of the product has aesthetic and symbolic value for consumers; also it can draw attention by giving consumers a quality impression and communicate ease of use.

From these studies, we can tell that giving a good first impression to customers is important for the product. When the customers' sensory system catches those stimuli from those products, and their perception gives them an understanding, we can know the product's color, shape, materials or other features from products, but which one can have a larger influence on customers? Let us talk about the color first. How does someone feel a color of the product? The book *Essentials of Psychology* said "the sensation of a color is the result from features of the wavelength mixtures striking the eye" (Bernstein, 2011, p. 93).

It means when we see a color, the first thing we see is just the wavelength. According to the sensory and perception theory, our eyes catch the wavelength of light and reflect this information to our brain, and then our brain tells us it is red or another color.

The definition of color is only the result of our perception received from the surrounding.

Many animals can only see the shades of gray and white; they don't have ability to tell the colors. For them, telling the basic shape of the surrounding is enough or they have another method for watching the world. Color is only the concept coming from the human and it doesn't exist in nature. With the appearance of the product, color is the most unstable aspect and can be

affected by many factors. Even a different person can see different color from the same product. For example, someone can say an apple is red and someone can say it is dark red. They are both right because of the different eye adaptors reflecting different wavelengths of light to their brains. And color also can be influenced by the surroundings. Putting an item in a dark room with green light or a room with sunlight yields a different color from same items.

Different from the color, the shape of the product also is a part of the appearance of the product. But it can be an inherent attribute of the product and it isn't as easily influenced by the surroundings as the color. And as discussed above, the sensory system and perception are the method for people to understanding items and the world. The book *Essentials of Psychology* introduced the process about how human convert light into images. There are some specialized cells called photoreceptors in the retina area of our eyes, which can convert light energy into neural activity; once they receive these energies (stimuli) they will transport this information to the brain, so our perception will tell us the image information. Those photoreceptors can be divided into two categories: one is a rod and another is called cones. Cones have three different light sensitive chemicals, which can make it the basis for color vision, and rods only have one light sensitive chemical, which means it can't discriminate colors. But the rods are more sensitive to the light stimuli. In dark or weak light environments, you can see the basic shape of the items, but it is hard to tell the color of that item. You can choose a shape of similar socks, but you may find out those are different colors when you see them in light environments. Those examples show humans are more sensitive to the shape of items than the color because of our sensory and perceptual systems.

When designers begin to design concepts such as brainstorming and sketches on paper, we usually use a pen to sketch some basic shapes with lines and then develop the details of the

product and color it. But it is rare for us to use a marker pen to give a paper color, and then use the pen for drawing lines to sketch the products. It is our natural behavior to consider the shape and the lines before the color when we do product sketching.

2.3.2 The Link Between Lines and Human Preference

> Line rarely exists in nature. But line does appear in the environment: the crack in the sidewalk, telephone wires against sky, bare branches in winter, a cable bridge. The visual element of line is used mostly to express the juxtaposition of two tones. Line is utilized most of often to describe that juxtaposition, and in this, it is an artificial device (Dondis, 1973).

It is hard to find a simple straight line in the natural world, because almost everything is born or made with curves except the light. Humans also come from the nature, so is that a clue to show that humans prefer the curved line to the straight line?

"The straight line belongs to men, the curved one to God" (Gaudi, n.d.). This sentence is the quote from Antoni Gaudi. It is not hard to figure out his attitude towards different lines from that quote and influenced by this preference about the curved line, Gaudi applied many exaggerated curved lines and waves to the architecture he designed. Those famous buildings are accepted and admired by people from all over the world, which means people like the buildings with the curved features.

2.3.2.1 Human Nature Towards Lines

When a human brain receives the information of the product contour, which consists of simple lines, the human preference will be formed. Different product contours convey different impressions to humans. As some research proved, the human visual system has a basic mechanism which can respond to low level stimulus features. Those stimulus features can

influence reactions and those reactions include the responses of aesthetic or human preference (Bar & Neta, 2006; Fechner, 1876). When our sensory system transports the line feature like line shape and line weight, our brain will produce some "feelings" towards those lines, like this line shape delivers a sharp feeling or rounded feeling.

Contours can influence how human perceive the objects and judge aesthetically no matter what kind of contour it is (Leder & Carbon, 2005). Human preference can be affected by contours because they convey different impressions such as threatening impression. Indeed, some research proved that the sharp transition in a contour can convey the sense of threat by using the vignette to test the human preference and emotion change about the sharp shape and round shape (Bar & Neta, 2006). From the research, the different type of contours, including sharp one and rounded one, would have significant influence on human attitudes towards the object they contact. Carbon (2010) also pointed out that contour is a basic element in how an object is seen; it shows how objects appear. For product design, there has been a recent trend towards designing a product which is rounded with no sharp shape, compared with the designed products from thirty years ago. Silvia and Barona (2009) also came up with a result that shows that humans have a preference for the objects which have a curved appearance and they are described as more beautiful and more pleasant.

According to those studies (Bar & Neta, 2006; Carbon 2010; Slivia & Barona, 2009) that we listed above, we can understand the sharp contour can deliver negative feelings to humans and signal for the human stay away, and rounded contour can produce positive feelings and signal for users to keep close to it.

2.3.2.2 Human Preference of Lines According to Social Message

When humans recognize the lines, their perception process will be influenced by the education and the social message conveyed. A concave line, which is recognized as smile-like line and a convex line, which is recognized as the frown-like line, will deliver a different social message to humans.

Research done by Lundqvist, Esteves and Ohman (1999) found that smile-like facial features and frown-like facial features will carry a strong emotional impact by studying the shape of facial features such as eyebrows, eyes, mouth, nose, and direction of gaze.

Those different shapes of facial features will deliver different social messages with positive or negative affective valence to human. When human receive those social messages with different affective valences, they will have different emotions. People will feel more uncomfortable in the presence of crying people. They would give more emotional support to the crying people and behave less aggressively. The facial expression can influence people's emotions, and people also have different individual response to different kinds of facial expression. The facial expressions, like fear and sadness, which carry the "help-seeking" social message, will relate to less emotionally stable and less aggressive perceptions (Hendriks & Vingerhoets, 2006).

From that research, we can learn that different facial expressions such as a smile (smile-like) and cry (frown-like) can cause different emotional results, but what about the line, which looks smile-like and frown-like? What kind of influence will it cause regarding human emotion and human preference?

In recent years, many scholars have worked on experiments and studies and have demonstrated that humans indeed prefer the curved object to the object with angles. Salgado-

Montejo, Leon, Elliot, Salgado and Spence (2015) studied human preference about different types. They describe four different lines: concave line (smile-like line), convex line (frown-like line), straight line and line originally absent on the product packaging to test human purchase preferences about them. From that experiment, they found that the concave line segment, which looks like a smile, can deliver a positive impact on consumers and implied a concave line produced a positive intention to purchase the product. Meanwhile, the frown-looking line segment will pass on a negative message, which exerts a passive intention and attitude for products.

From the purchase preference, human prefer the product packaging that has a smile-like line because it carries a better and positive social message. For the product itself, it also attracts people's attention by different line shapes.

Chapter 3

The Development of Design Guideline

Since the lines exert a great influence on humans, there is a problem. How to apply lines into the product and make the product more understandable and beautiful to influence the human preference?

For the first part, we need to analyze the human perceptions of lines, then figure out how to make the product outline more understandable based on product semantics. Finally, we need to combine the human preference to the lines to improve the product's appearance.

3.1 Methods of Analyzing Lines in Perception

3.1.1 Convert Three-dimensional Product to Line Drawings

When we get a product and need to analyze the lines in that product, the first step we need to do is to figure out how to convert a product in three-dimensional form into the two-dimensional form because based on the understanding of lines, they only exist in the two-dimensional world.

As we mentioned in the literature review, the three view drawings work as a main tool to measure and describe the line shape of a product, and it can be our main tool to transfer the product from three-dimensional views into two-dimensional views. The function of the three view drawing is similar to our sensory system. Our sensory systems, like the eyes, catch the outside information as a photo, and then transport the main features of the contents in this photo to our brain. Of the three view drawing method, it can catch one-angle views of the product and then just focus on the main shape of the product while ignoring the other factors, like product color and product material.

From the three view drawing method, we can get the line shape of products from different angles like front view, back view, left side view, the forty-five degree views and even many different angles of views. All those views are formed by different lines.

There are many existing software programs that can help us transfer the three-dimensional product into the two-dimensional views and draw the line shape drawings, such as *Solidworks*, *Adobe Illustrator* and etc (See Figure 14). For the existing product, the first step is taking product photos with the angle you want to analyze. Then you can drag that photo into the software *Adobe Illustrator* to create a file. Then you use the command "convert to Grayscale" under the "Edit colors" category to delete the product color. Then combine the command "Image Trace" under the "Object" category with the pen tool to draw the line shape of the product (see Figure 15) so that we can reduce the influence of the product materials.

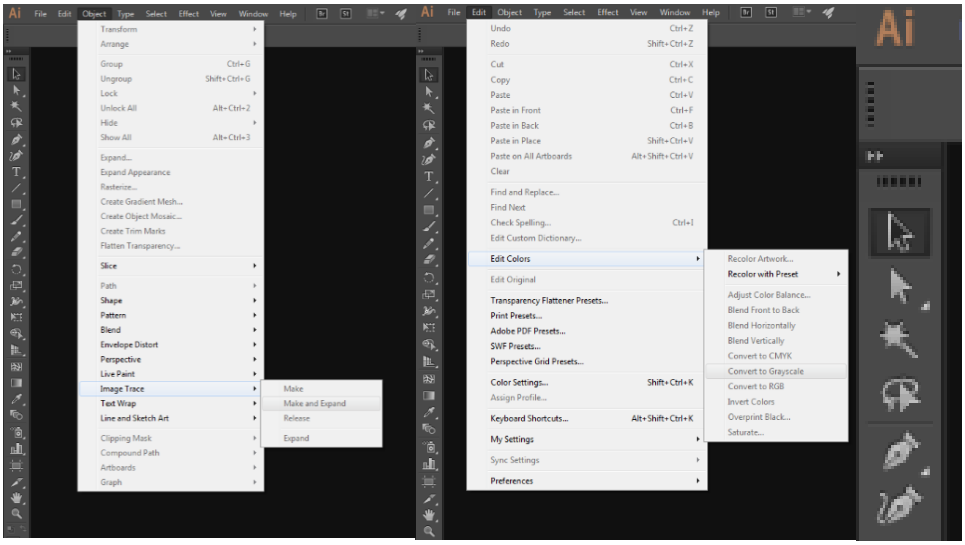


Fig 14 Example of software to trace lines

Figure 15 The line shape of the product

For the three-dimensional computer model, we can use software *Solidworks* to get the line shape drawing.

3.1.2 Catch The Line Features According To The Human Sensory System

After getting the line drawing of the product, we can start thinking about the main features human sensory systems get from the line drawing. As I mentioned in the literature review, the human sensory system will receive the stimuli from the outside and transport the main features to the brain.

Because the line drawing is a two-dimensional picture, the main sensory method the humans use is the eyes. It means it will not have other stimuli like sounds, pressure, texture or odor, and it just has the main features which can be caught by human eyes such as line curvedness, line length and so on.Those features can be regarded as the common feature of lines because those features exist in each line.

3.1.3 Catch the Lines Meanings According to the Human Perception

After our sensory system transports those main features of lines, our brain will compare those features with the “data” in our database, and then tell us what line shape it is and how long

it is. From this step, our sensory system and perception work together and we have the basic understanding of lines. For example, we can know this is a concave line and not a straight line according its curvedness, this line is longer that other line and so on. Those understandings can be the same because the human share the same sensory system and they can catch the same features from the same line drawings.

But there are also some differences in perception among people because the perception can also be influenced by knowledge and the experience, which can influence the understandings of the lines. After understanding the main physical features of the lines, we also need to figure out the meanings or connections between lines and other things, which are influenced by many factors, such as the concave line can represent the smile-like face and the convex line can be regarded as the frown-like face and according to this perception and understanding of those lines, many brands apply these rules to design their logos.

Figure 16 Example of Smile-like lines

We can see many famous brands (see Figure 16) using the concave line as their logo features to represent a smile face and attract people's attention, trying to give a good understanding and impression to people.

Besides the understanding of the single lines, when we connect each line to a whole part, we usually can get a shape such as the circle, the triangle, the square or even the organic shape.

When we look at those shapes, our perception also will work and then we can get some association in connection with those line shapes.

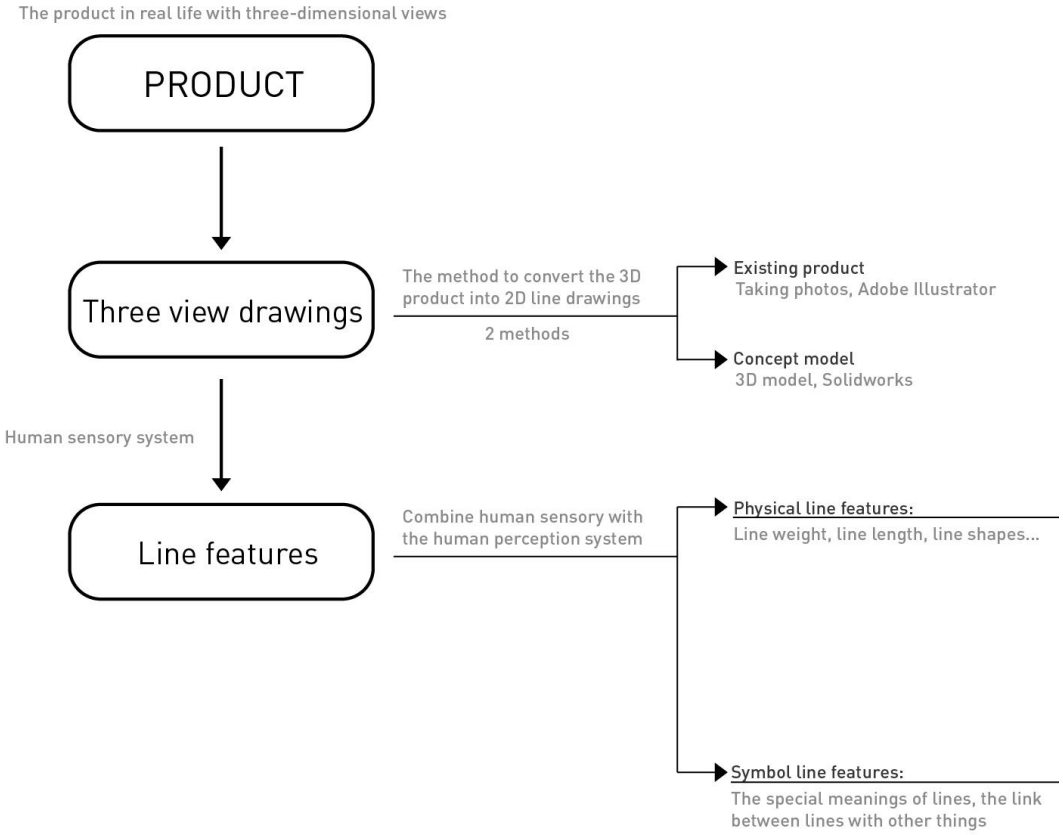


Fig 17 Part of process of analyzing lines features

Figure 17 shows the whole process of the analyzing line steps according to the human senstory system and human perception.

3.2 Methods of Analyzing Lines in Product Semantics

Users will feel comfortable when they stay with the thing they can understand, so for the product, having understandable features is important and makes sense. In the features of lines, we divided the line features into two parts: the first part is the physical features of the line, which can be detected by the human sensory system directly and include features such as line shape,

line length and so one. Another part is the symbol of the line, whose features are influenced by the human perception and have strong links between other things.

3.2.1 Calculate Physical Line Features

For the line drawings, the line shape and the line length are the physical features that can be received from the human sensory systems, and all lines have those physical features which means those line features can be calculated. Based on the human understanding, what kind of line can be regarded as the beautiful line? As we discussed in the literature review, the Golden ratio is regarded as the perfect number and the Fibonacci spiral is the perfect shape no matter if it is in a natural area or the human artifact area.

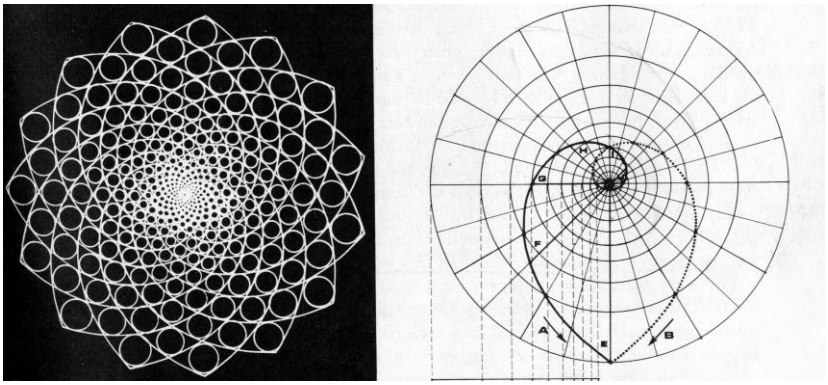


Figure 18 Dinergy pattern in natural items

In the book of *The Power of Limits*, Doczi (1981) also came up with a method to calculate the shape of lines in artifacts to analyze if those lines are close to the golden ratio. He came up with a concept called “Dinergy”. Dinergy is a pattern-forming, which can be found in the natural items such as the pattern of the florets (see Figure 18). He applies this Golden ratio to calculate methods in the natural objects such as the flowers to calculate the “beauty” in the flowers (see Figure 19).

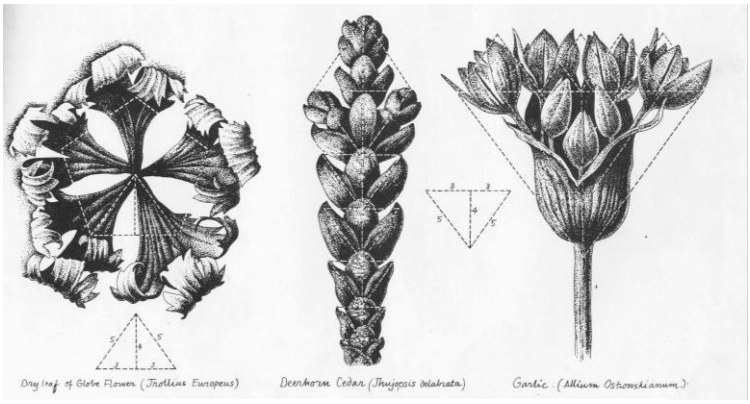


Figure 19 Dinergy pattern in flowers

Doczi also used this method, finding the link between the golden ratio and beauty of artifacts. Additionally, he calculated the proportions in many geometric shapes and proved the golden ratio also exists in those shapes (see Figure 19). The golden ratio not only just exists in the natural objects and geometric shapes, but it also exists in artificialities. The keys of a piano are also designed by following the Golden ratio (see Figure 20).

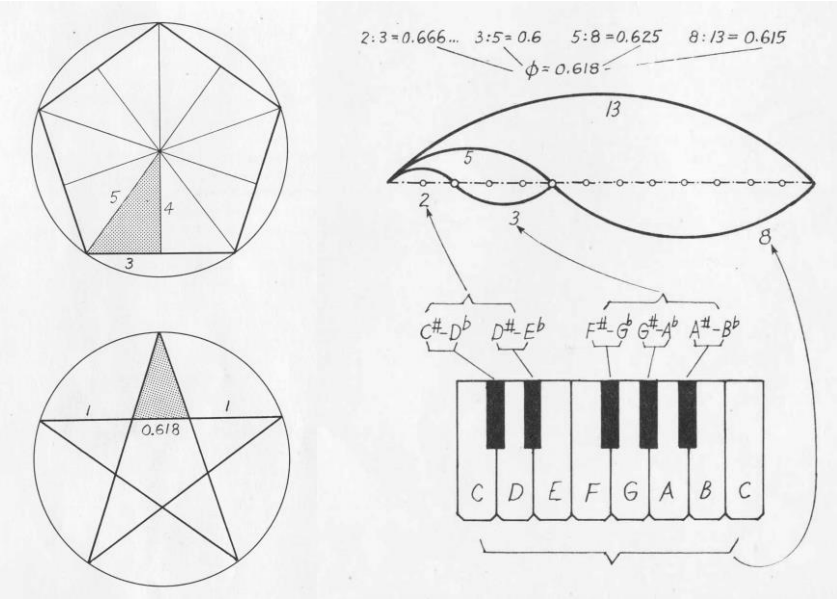


Figure 20 The Golden ratio in geometic shape and piano

The method for analysis of the golden ratio can also be applied in many design products. Doczi also used this method for analyzing why some vases and fictile items look beautiful. From the pictures we can tell Doczi calculated the proportions of the lines in two traditional grass hats and found the main proportion of the curve shape is close to the golden ratio (see Figure 21). And he also analyzed many similar hats in different areas and the results showed that the curved part of those hats all followed the Golden ratio design.

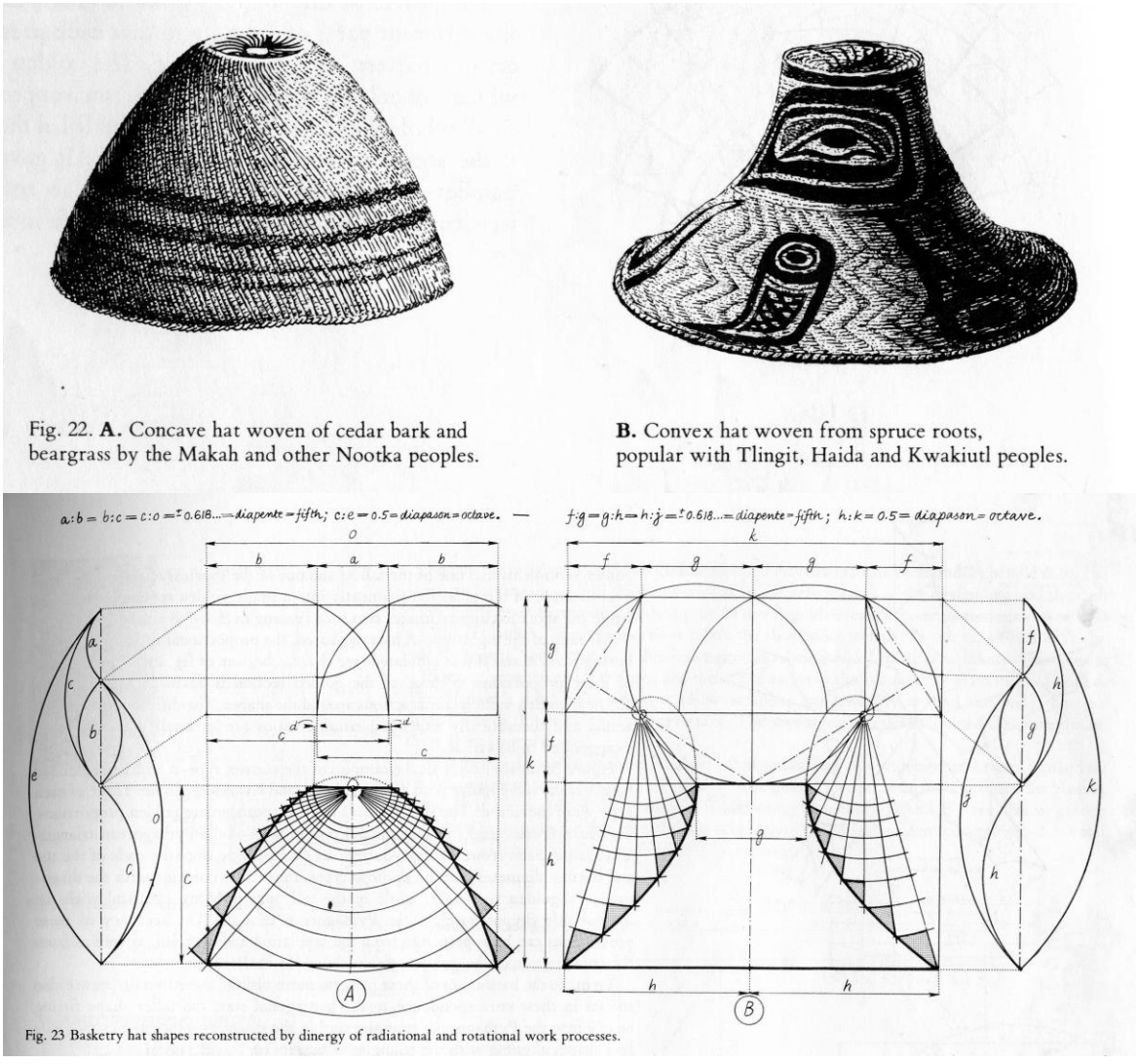


Figure 21 Golden ratio in grass hats

And the same situation also happened with the vase below (see Figure 22).

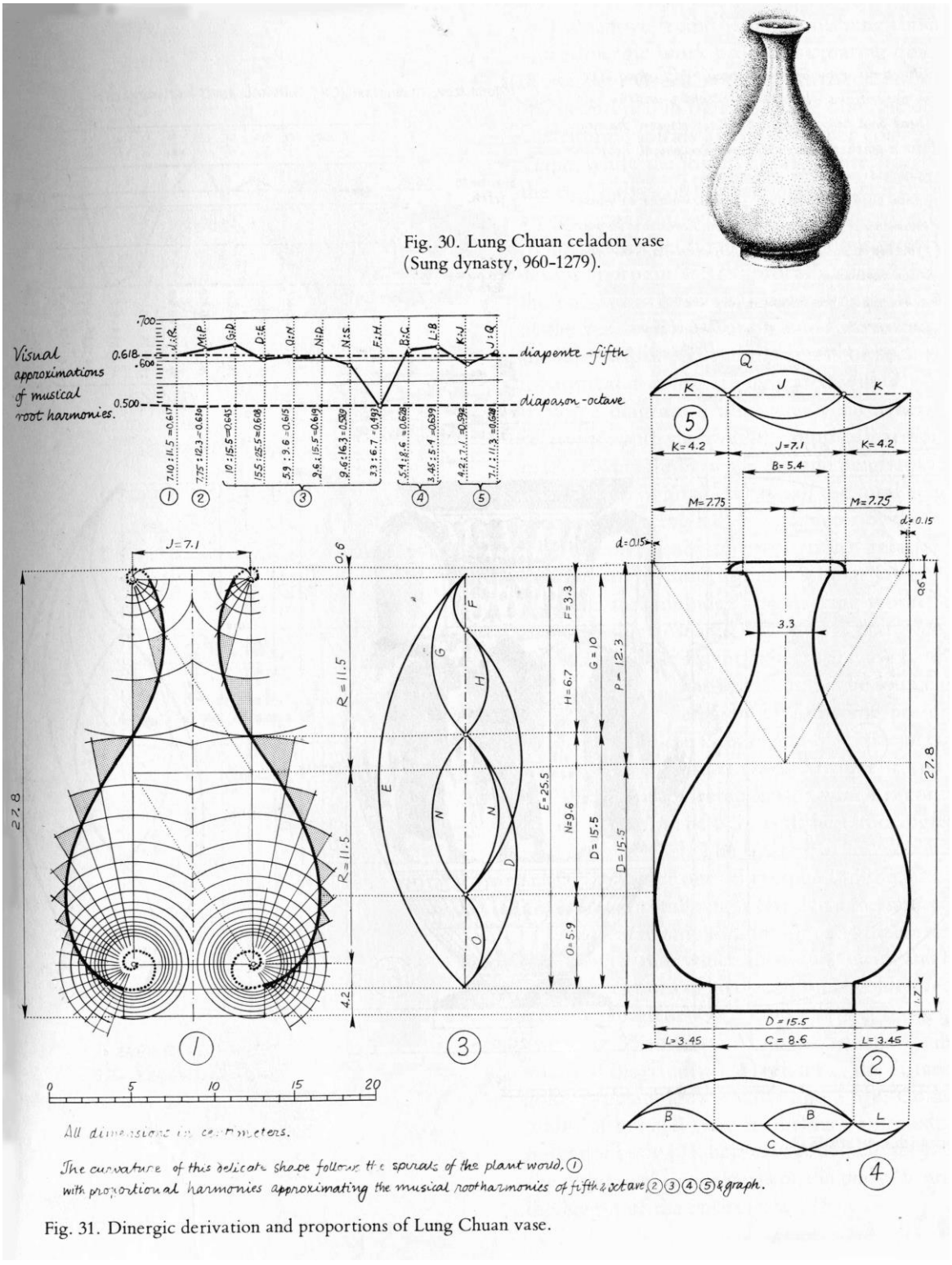


Fig. 31. Dinergic derivation and proportions of Lung Chuan vase.

Figure 22 The Golden ratio in vase

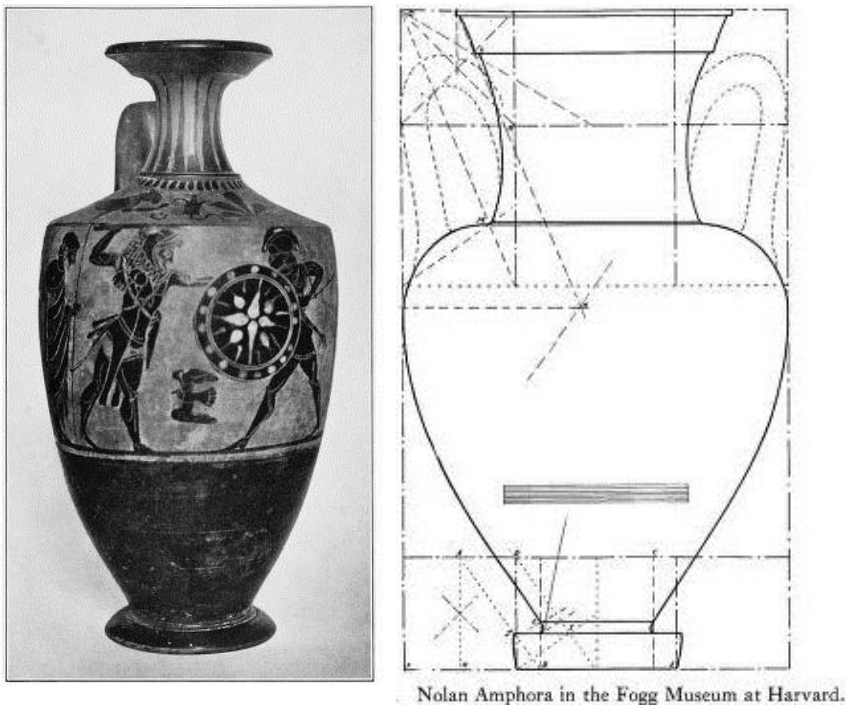


Figure 23 *Nolan Amphora in the Fogg Museum at Harvard*

Hambidge (1920) also used the similar method to calcaute the proportion of the vase (see Figure 23) in his book *Dynamic symmetry: the Greek vase*.

We also can apply this method to calculate the line shapes in the product to see if their proportion is close to the golden ratio. Additionally we can use this method to come up with some curved lines with Golden ratio features.

3.2.2 Three Situations for Calculating Physical Line Features

There are three situations that may appear in the line shape drawing: only having curved lines, only having straight lines or having curved lines and straight lines both.

For Situation One:

If the product only has straight lines, it means we don't need to calculate the curved lines' Golden ratio proportion. It represents the most simple situation; we just need to calculate the length of each straight line and the whole proportions of lines.

Here is an example: the design of the Porsche Hard Drive. The main feature of the Porsche Hard Drive is straight line design. The whole product only uses the straight line to make up the whole body without the smooth transition. The product in picture is the LaCie 3TB Porsche Design Desktop Hard Drive USB 3.0 version hard drive (see Figure24). I will use it as an example to introduce how to analyze the product line shape which only have straight lines.

Figure 24 LaCie 3TB Porsche Design Desktop Hard Drive USB 3.0

Step one: Since it is an existing product, we need to get a photo which shows one view of the product and then use the software *Adobe Illustrator* to get the line shape of product (see Figure 25).

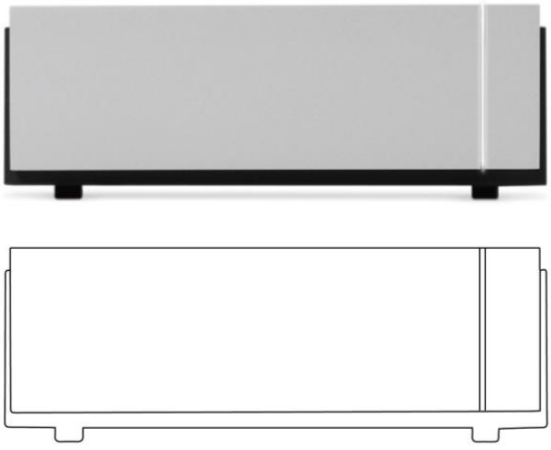


Figure 25 Line shape of the hard drive

Step two: Using measurement tools to measure the main dimension of lines (see Figure 26).

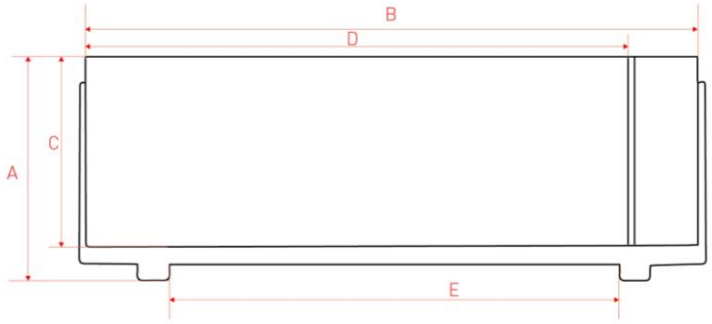


Figure 26 Measure the dimension of hard drive

From the picture, we can get the length of the lines:

A=2.03 B=5.55 C=1.73 D=4.92 E=4.07

Step three: Caculate the scales in each length of lines and get the form chart.

B/A=2.73 D/A=2.42 E/A=2.01

B/C=3.21 D/C=2.84 E/C=2.35

Step four: Compare with the standard Golden ratio number.

For Situation Two:

Besides the product which only have the straight line, there are also some products that only having an organic curve shape which means they don't have straight lines in line shape drawings. Then how to calculate their curve lines? Different from Situation One, in which only the length of the straight line needs to be calculated, we need to use another method to calculate the scales.

Here we will use the example we mentioned before, the outline of a Dell mouse. Since we already got the line shape drawings of it, we can tell the basic shape of this Dell mouse is an organic shape. I will introduce the method of analysis of this curved shape below.

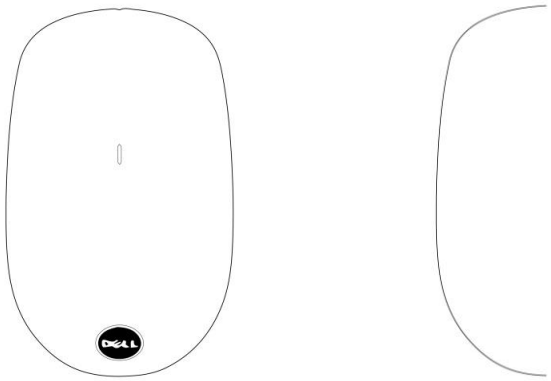


Figure 27 Line shape of the Dell mouse

Step one: We need to input this shape into the software *Adobe Illustrator*. Then the details of the picture, such as the logo, needs to be deleted to reduce the interference factors. Because this shape is symmetric, we just need to analye one half of this line shape drawing (see Figure 27).

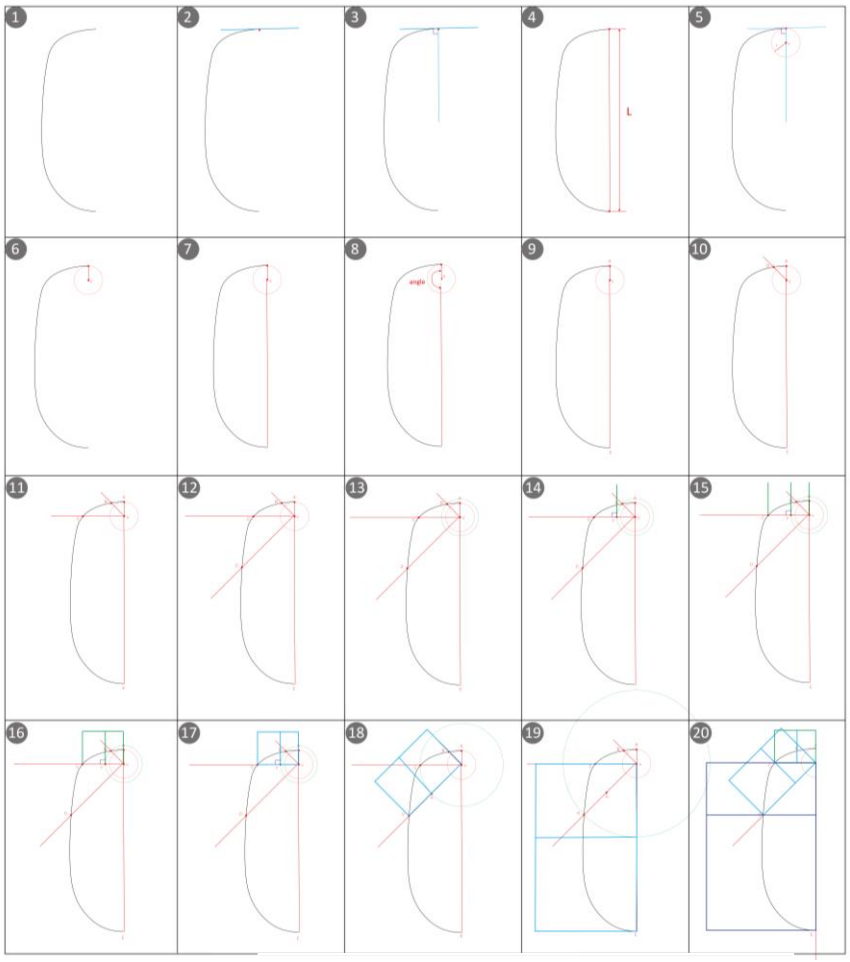


Table 1 Details of step two

Step two: Follow the steps shows in the Table 1 to get the Golden ratio calculate squares (see Table 1).

1. Get the half line shape because of the symmetrical structre.

2. Find the start points of the curve line and get its tangent line.

3. Get the vertical line based on the tangent line and start point.

4. Measure the distance between the start point and the end point of the curve line to get “L”.

5. Calculate the radius of the cirle based on the formula and locate the center of the cirle at the vertical line.Mark the center point as point O.

$$R=0.156L$$

6. Connect the center of the circle, point O, and the start point of the curve line, point A.

7. Connect the center of the circle, point O, and the end point of the curve line, point E.

8. Measure the angle between the line segment: OA and OE.

9. Decide an degree which can divide that angle into the equal parts.

10. Get the first line segment based on that degree and line segment OA. Mark the intersection point of the first line segment and the curve line as point B.

11. Get the second line segment based on that degree and line segment OB. Mark the intersection points of the second line segment and the curve line as point C.

12. Get the third line segment based on that degree and line segment OC. Mark the intersection points of the third line segment and the curve line as point D.

13. Create a circle which share the same center point of Circle O. And it also has to across point B.

14. Mark the intersection point of that circle and line segment OC as point F. Create vertical line based on point F and line segment OC.

15. Create the same length vertical line segment which across point C and Point A.

16. Connect the end points of those lines to get a square.

17. Get the square CO.

18. Use same method to get square DO.

19. Use same method to get square EO.

20. Start to Step three.

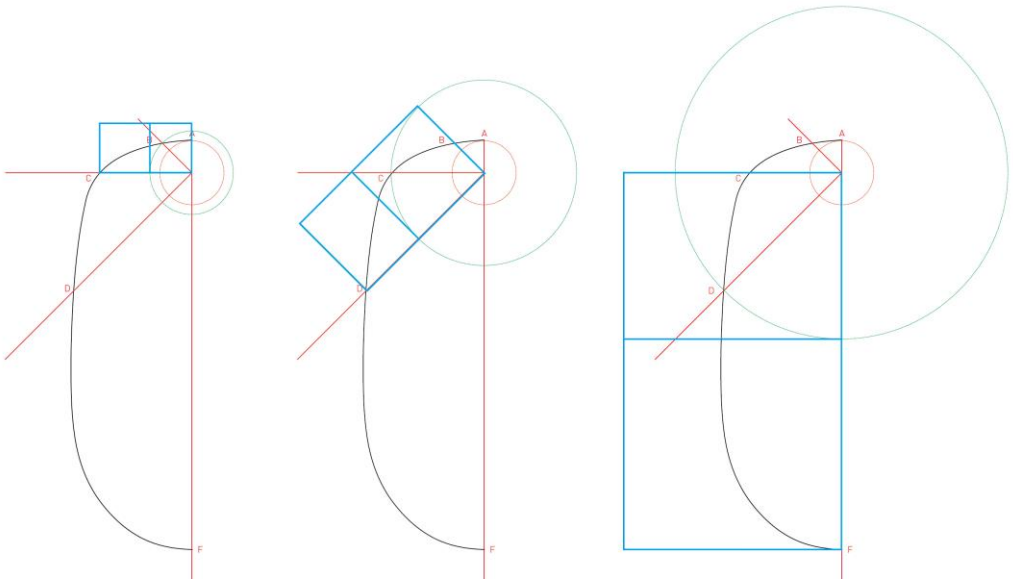


Figure 28 Squares in curve line

Step three: Pick up those squares in the drawings and begin to measure their dimensions Get the length of a, b, c, d, e, f. (see Figure 28 and Figure 29)

The length of the lines:

a=0.92 b=0.76 c=1.31 d=1.63 e=3.84 f=3.02

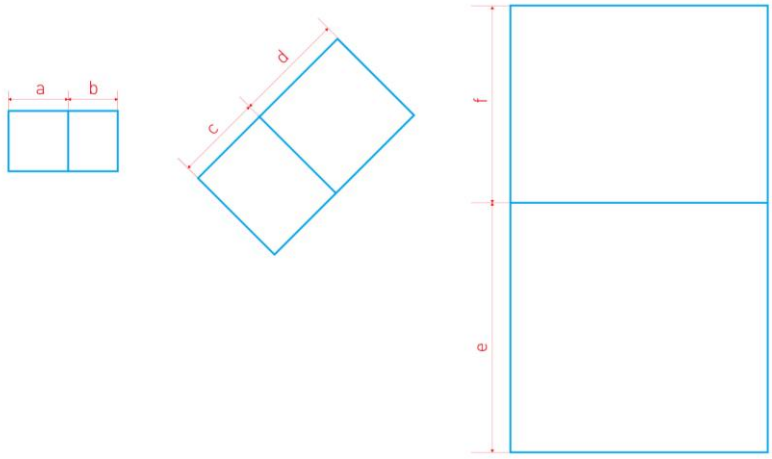


Figure 29 Squares with dimension

Step four: Calculate those lines and compare it with the Golden ratio.

a/b=1.21 d/c=1.24 e/f=1.27

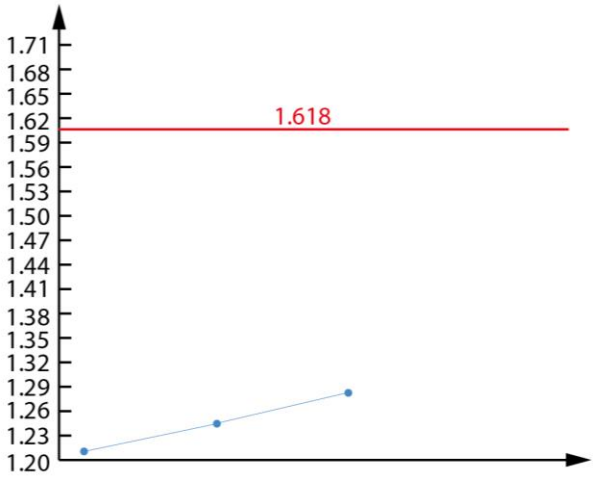


Table 2 Calculation of the square

Step seven: Obtain conclusion (see Table 2).

Conclusion: From the chart, we can tell the third square is close to the Golden ratio square, and the first square is the most unsimilar to the Golden ratio square. It means the curve line between point D and F most looks like the Golden ratio curve and the curve line between A and C has a big difference with Golden ratio curve.

From this conclusion, we can tell which part of the curve line needs to be redesigned.

In order to prove the correction of the calculation result, I aslo calculate the same line which is divided by different angled dividing lines.

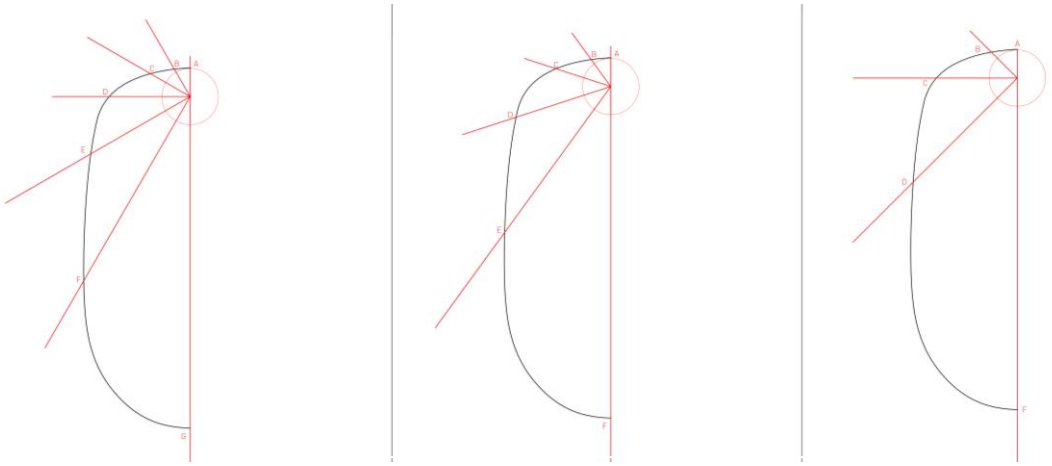


Figure 30 Same curve line with different dividing lines

In Figure 30, the same curve line was divided into the different parts by dividing lines. The first curve line was divided by 30 degree dividing line, the second curve line was divided by 36 degree dividing line, and the third curve line has the 45 degree dividing lines. According to the Golden ratio calculation method, I got their Golden ratio suqares (See Table 3).

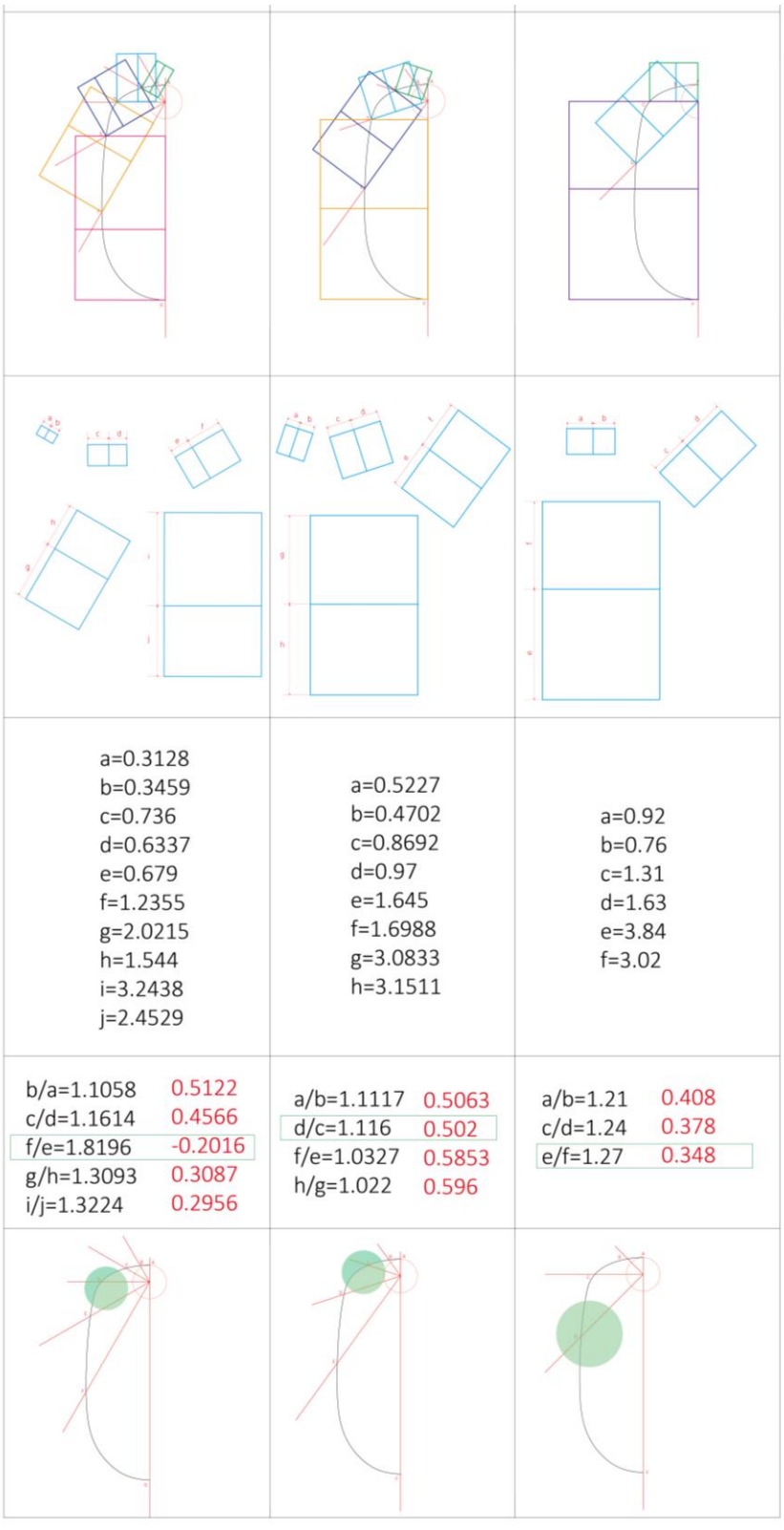


Table 3 The Golden ratio squares in curve lines

After analyzing the results getting from Table 3, we can easily find which part of line need to be refined. And in Table 3, we can find out that no matter how many parts that curve line divided, the part which need to be refined is still at the same position. It means that calculation method is reliable.

For Situation Three:

Most of time the product will not only have curved lines or the straight lines, but it will have them both. In order to analyze the lines in that kind of product, we have to combine the methods which are used for analysis of the straight lines and curved lines.

Here is the example for us to analyze the combined lines, the center part of the Dell mouse (see Figure 31). We can notice that part combines curved lines and straight lines.

Step one: We still need to put the line shape drawing into the software *Adobe Illustrator*, and then separate the curved lines and straight lines.

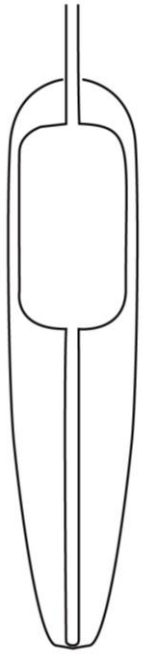


Figure 31 The center part of Dell mouse

Step two: Start to analyze the curved lines according to the method provided in Situation Two. Analyze the squares drawn in the curved lines (see Figure 32).

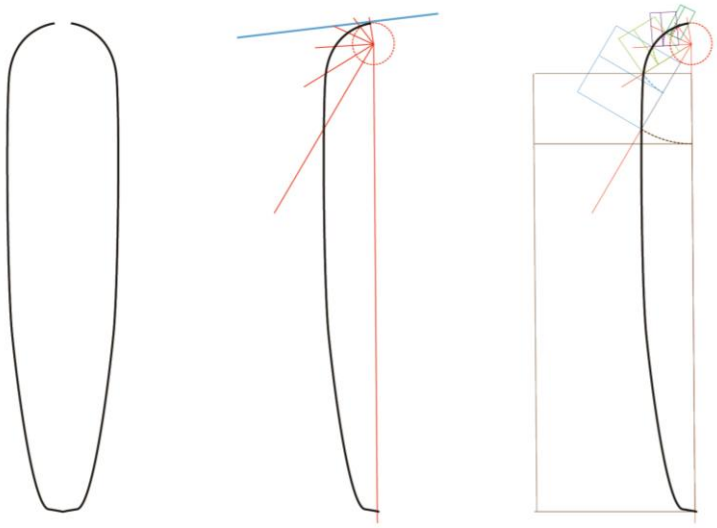


Figure 32 Squares in lines

Step three: Calculate the square dimensions, and then compare with the Golden ratio to understand which part of the curve needs to be refined.

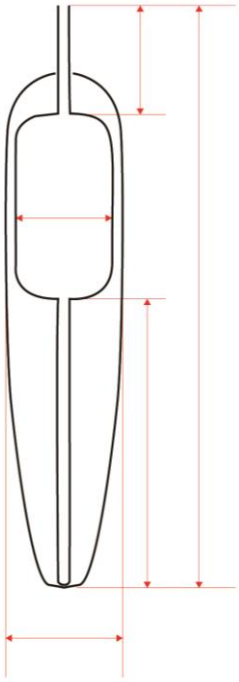


Figure 33 Measure dimension

Step four: After calculating the curved line, then we need to calculate the whole line shape, which combines the curved lines and straight lines (see Figure 33). Measure the main dimension in the main part of the line shape, and then calculate the size. Compare the result to the Golden ratio to know where the product needs to be refined.

3.2.3 Example of Calculating the Physical Line Features in Product

After introducing the method of calculating the physical lines, we need to prove this method correct with a real product. Therefore, I applied this method to four different mice, which are the same brand.

The mice I used to calculate are as follows (see Figure 34):

Logitech Wireless Mouse M185

Logitech Wireless Mini Mouse M187

Logitech Bluetooth Mouse M557

Logitech - M325c Wireless Optical Mouse

Figure 34 Four mice

The main features of these mice is their price is similar, approximately15 dollars, and they also shared the same brand, which is Logitech.

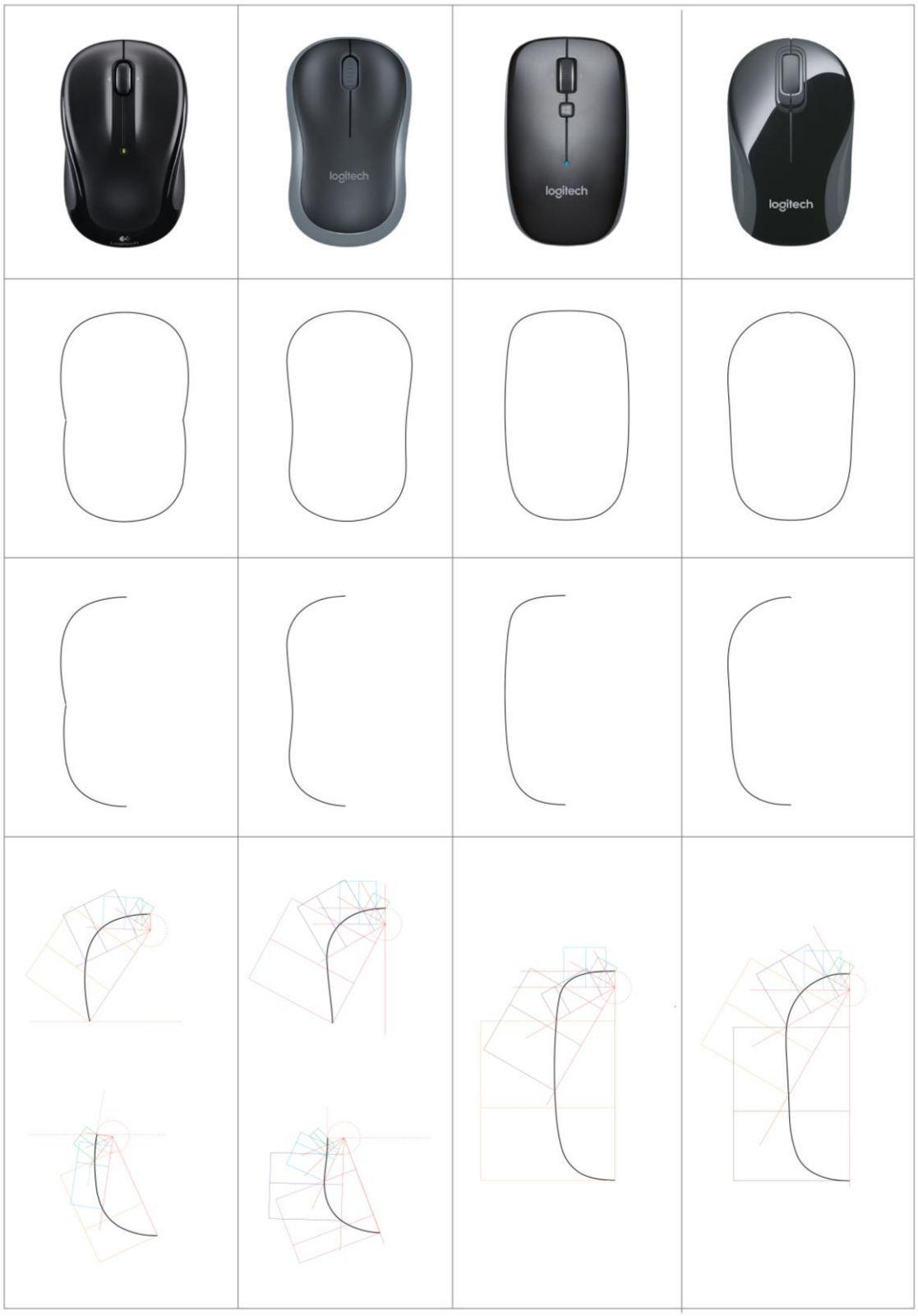


Table 4 Squares in these four mice

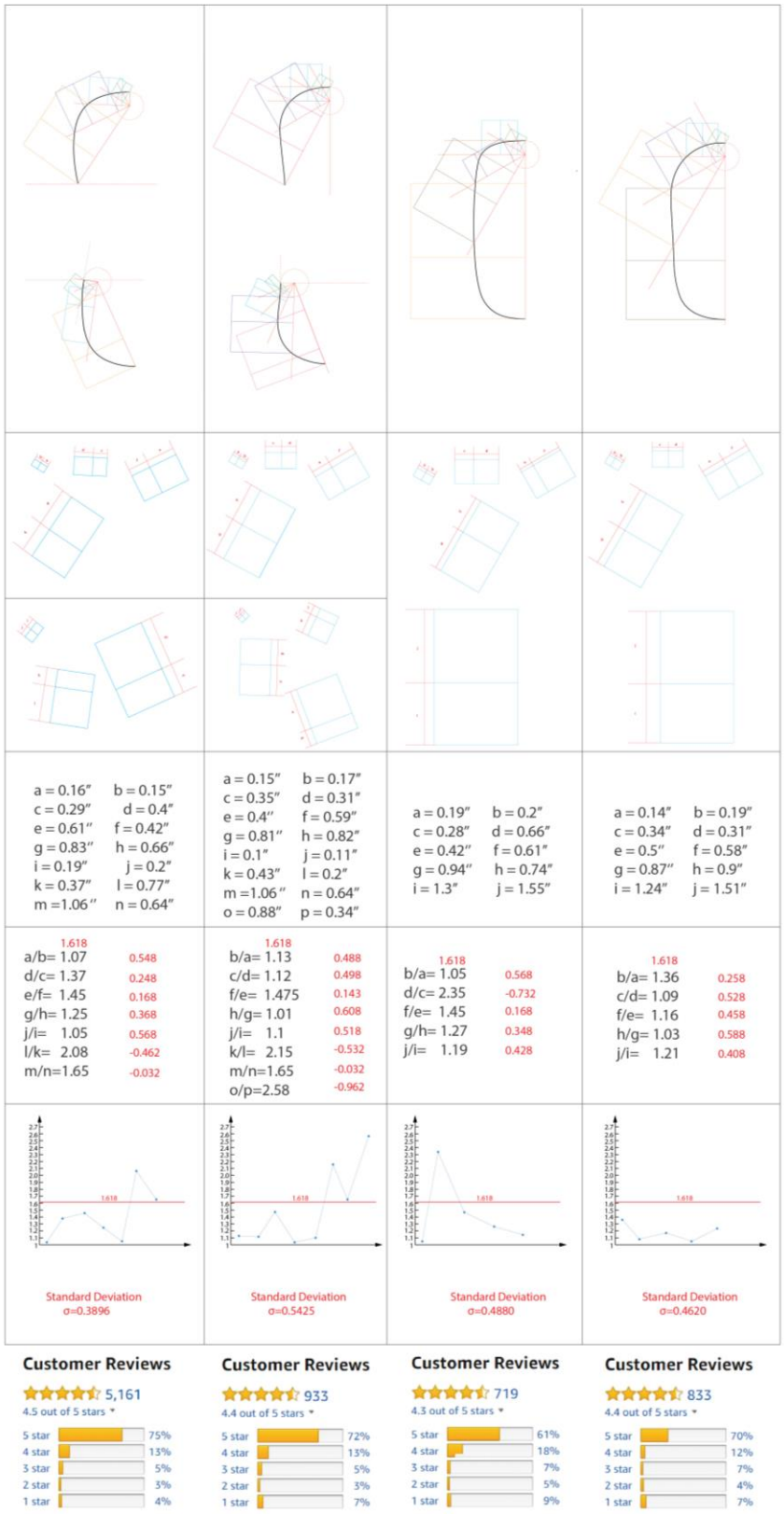


Table 5 Analysis of these four mice

According to the methods discussed above, I calculated the lines in these four mice and obtained four standard deviations: 0.3896, 0.5425, 0.4880, 0.4620 (see Table 4 and Table 5). The smaller of the standard deviation, the more similar to the Golden ratio line. It means the line in the first mouse is most similar to the Golden ratio line and following sequence is the fourth one and the third one. From the “Customer reviews” from the Amazon.com, we can tell the first mouse is the most popular mouse of these four mice and we also can tell a trend, that the smaller of the standard deviation, which presents a similar level of the Golden ratio, the more popular the mouse.

	Easy to set up and works well By alfarine on May 27, 2017 Color: Francesca Fox Verified Purchase very cute looking. Easy to set up and works well. Works great! By Mom2three on May 29, 2017 Color: Francesca Fox Verified Purchase Cute, compact design. Works great! Five Stars By avid reader on May 29, 2017 Color: Blue Harlequin Verified Purchase Pretty. Works great. easy to use By S. Harris on June 27, 2017 Color: Red Verified Purchase Cute, small, easy to use. Works perfectly. I love it. Love the look By Brittny Dobson on July 10, 2017 Color: Francesca Fox Verified Purchase Battery lasts about six months with daily use. Love the look! Owl that caught the mouse also caught my eyes! By Book Worm on January 17, 2016 I like the vibrant colors of this owl designed mouse. This is a Logitech mouse with an on/off switch on the bottom to save battery power. This came with a battery, and it is always a pleasure to buy something I can use immediately out of the package! The wheel to scroll is quick and smooth. This is by far my favorite, inexpensive, wireless mouse that I have ever owned. I purchased it to compliment a colorful owl mouse pad Elonbo TM 8.6 x 7 inches / 220 x 180 mm Cute Owl Design Waterproof Neoprene Soft Mouse Pad. My co-workers are jelous :) By schelly on June 29, 2017 Color: Teal Chevron Verified Purchase Super cute mouse and seems to work great so far. Pretty but didn't last long By Mathilde Sexton on June 26, 2017 Color: White Paisley Verified Purchase It is pretty but it stopped working after only a few months. Perfect By angie choi on June 19, 2017 Color: Pop Circle Verified Purchase Really cute design and love how the wheel doesn't make the clicking noise as the previous versions. Beautiful. By Teresa Wiggins on June 9, 2017 Color: Purple Verified Purchase Beautiful design, I can tell it's printed into the material and not stuck on. I've had it a couple months already and no fading. (I use my computer approx. 10 hrs. a day, 7 days/wk.) The roller is smooth and it and the side grips have a nice soft, suede feel. I love that it has an auto shut-off feature so I can just leave it set to on. I have yet to change the batteries.	10/150	Customer reviews 5,178 4.5 out of 5 stars 5 star 75% 4 star 13% 3 star 5% 2 star 3% 1 star 4%
	Not sold on ~~Invisible Optic~~ but great otherwise By Longpig on June 23, 2015 Color: Gray Verified Purchase This is a cute mouse - fits the hand perfectly. One issue I had and I'm not sure why Logitech thought it would a good idea. Maybe some people do like it but I hate it and the one thing that stopped this getting 5 stars. When I first put in the battery and turned it on the optical light did not turn red. Put in the receiver - it came up..still no red. Changed batteries - no red. Thought it was defective till I looked at the tiny TINY writing on the bottom of the mouse. This mouse uses ~~Invisible Optic~~ so that means no red light. No light up at all. Why is this a good idea? I move the mouse around sometimes - not working - gotta run down the full list as to why it's not working - no receiver, battery dead, turned on or off. Mouse suddenly stopped working? Is it lag? Battery dying/died...what? Hard to beat this mouse By Matt E. on March 10, 2015 Color: Gray Verified Purchase Compact mouse but curved enough to not feel like you're holding it with your fingertips. Connected with Windows 8.1 immediately without any installation or problems. I wasn't even sure it was connected until I set it down and saw the cursor move. Awesome little mouse for a laptop. Pros: Cheap, feels sturdy, and takes standard batteries. Also there's a little slot in the battery compartment to store the USB dongle when you're not using it. Good thinking from the designer. Excellent replacement (so far) for an older Logitech mouse By Thomas E. Hudson on April 14, 2015 Color: Gray Verified Purchase I bought this to replace a Logitech M515 mouse that gave up after 5 years. Setup on my Macintosh took 5 seconds. It would have been less but I opted to use the new wireless dongle rather than the old one. That old one I have placed in the little slot inside the battery compartment for safekeeping. Surprisingly, I did need to go into my Preferences and slightly adjust the speed at which the cursor travels relative to mouse movement, but that was another 7 seconds. Not a big deal! I like that this mouse has gone from 2 batteries down to a single AA battery. It makes the mouse lighter. The curvature of the top is what I was used to and that is great. It reduced hand fatigue and fits perfectly in my 7.25-inch (wrist to finger tip) hand. Button travel is slight and provides a slight, tactile click so you know you've done it. Solid Wireless Mouse for the Cheese! By Savvy Shopper on May 29, 2017 Color: Gray Verified Purchase I have always had Logitech mice. This is a nice size - not too slim or round. I have a medium sized women's hand. Works great. Installed battery, turned on and it was ready to go. Like that the newer ones have the smaller wireless input piece. Reasonably priced and saved me a trip to the store which I love. Nice sleek look By Sothac101 on March 17, 2016 Color: Gray Verified Purchase Nice sleek look. Super comfortable and forms to my hand easily. I have smaller hands so sometimes computer mouses will be too bulky and uncomfortable to use. This one is just perfect. And my husband who has very large hands is able to use it with ease. Very impressed especially for the price. Very good and efficient mouse. By Casey Clifford on September 28, 2016 Color: Gray Verified Purchase Ease of use: 10/10. The mouse was up and going within 10 seconds of plugging the USB responder into my laptop. The mouse tracks extremely well without the need of a mouse pad. Design: 7/10. The appearance of the mouse is mostly generic. The one cool feature is that the USB responder tucks inside the battery door so you won't lose it when transporting. Overall: 9/10. Very good mouse, especially for the price. The only minor annoyance is the louder than normal click sound from the buttons.	6/150	Customer reviews 1,791 4.4 out of 5 stars 5 star 71% 4 star 13% 3 star 5% 2 star 4% 1 star 7%

Table 6 Customer Review of the appearance

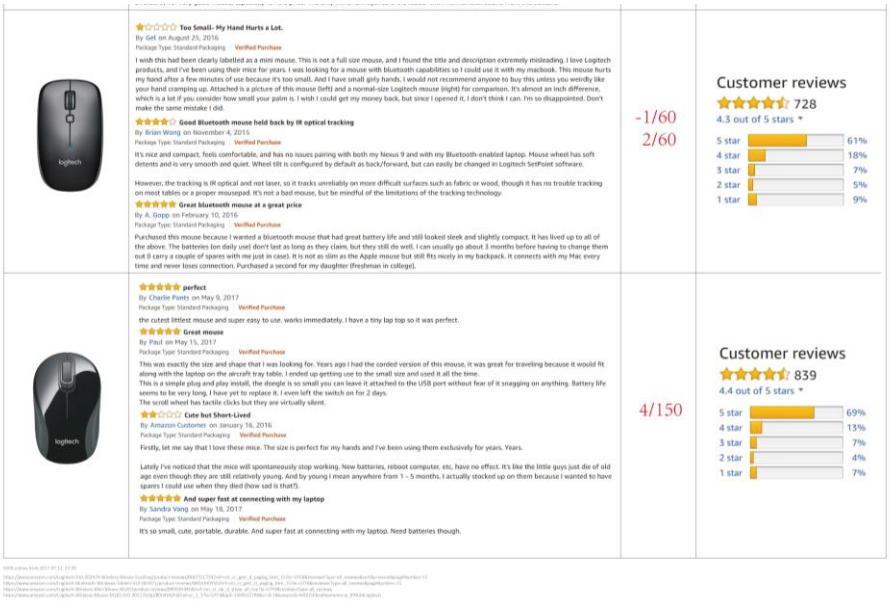


Table 7 Customer Review of the appearance-2

Also, I collected the 150 comments of each mouse from amazon website and we can see from the Table (see Table 6 and Table 7): the first mouse got 10 positive comments in 150 comments, second mouse got 6 positive comments, the third one which has most differences with Golden ratio line got one negative comment and 2 positive comments, and the fourth mouse got 4 positive comments. This result is close to the assumption we get from calculating similarities to the Golden ratio. Therefore, we can conclude that the methods of calculating the physical lines in product according to the golden ratio work well.

3.2.4 Calculate The Symbol Line Features

Besides the physical line features, line shape also has the symbol line features. When human sensory system notices a line, it just tells the physical line features such as the length of line and the curvedness of lines. Then after the information from the human perception is carried to the brain, human will have some recognition of the lines, like what this line looks like or what it represent, or they may make some links between those lines with other things.

Figure 35 Shark fin

Here are two pictures (see Figure 35): one is only a drawing made of lines and one is the photo of the shark fin. It is easy to make links between these two pictures when they were listed in the same place and everyone knows that this line shape drawing represents the shark fin. But when we just see that simple line drawing, we still can recognize that shape of the lines and make links between the drawing with the shark fin. Our perception gave the meanings to simple line drawings.

When people start to understand the line shape, they not only just understand the basic physical features of the lines such as line length and the line shape, but they also can understand the meanings of the lines, what they represent, and even link the line to other objects. So we can not only use Golden ratio calculations to judge the physical features of the lines, but we also need to find a way to judge the symbols of lines.

Because the goal of the product semantic is helping people understand the product, the method of the product semantics can be used to help figure out the standard of the judgement of lines. According to the theory of the Krippendorff's research, he provides three methods to develop the product semantics which can increase the understandable level of the product.

The first method is “Descriptive”. As the meanings of the word, when designing the product, we need to conduct discourse analysis to figure out and understand why and how people do what they do. It's like a motivation or expectation for people to imagine the product. When people want something, they can give a description, like I want something that can mix the cream and also peel the banana. Before we design the lines in product, we have to figure out the main purpose of the lines and find the “description” behind the lines. We must figure out the anticipated results of these lines and the interaction between the lines and users. We must judge if this line finishes the product functions or just increases the interaction influence between the lines and the users and so on. For example, if this line shape was given a “button shape” description, it will represent the button if people see it. People expect a button shape when seeing this line shape. If it fits this description, it can be a good designed line. It helped people to understand that part of the product.

“The second class of methods is anticipatory or interventive and seeks to extrapolate from know understanding of things the changes in understanding and practices a new design might introduce” (Krippendorff ,1989). The second method he mentioned is improving the product semantic of product based on the human known understanding of items. Understanding the things we are involved in can increase the sense of identity to the product. Krippendorff (1989) found out when people understand the role the product plays and gets a satisfactory explanation of the details of the product, they will say that the product “makes sense”. When people produce an expectation, they will produce an anticipated guessing result based on their perception “database,” which is influenced by stimuli from outside. They will basically imagine what the basic look of a product can be. So when they finally look at a similar product which fits their imagination, they will call the product familiar and as making sense. Following this theory,

which means the lines in products have to be understandable and be familiar to the users, this idea can increase the user satisfaction with the product.

For the lines in the product, it requires when we design the lines, we need to do so based on the basic cognitions and understandings of the user to design the line features.

But because the user keeps learning from their surroundings and the experience, their cognition, learning, and social interaction has kept changing, which means their understanding of the items can be a dynamic process and product semantics can be also a dynamic theory.

The key word of the third class of this method is “creativity and intended to support informed design decision.” When a product is only designed based on human understanding and doesn’t have any creativity, the product maybe looks boring. Finding a creative design that achieves the basic function of the product is an important part of the product semantics. Creating the “different lines” in the product and indeed solving the problem is the third standard to test if the product fits the product semantics rules.

3.3 Methods of Analyzing Lines in Human Preference

As discussed in the literature review, humans use sensory system and perception to understand the items and recognize the world, and product semantics method help product more understandable. After understanding the thing they detect, the human will produce the preference to let them know if they like or dislike the things they found. Human preference will also influence the human sensory system and perception. That's why if you like something, you will always notice it in a short time and if you dislike something, you will usually ignore it or just pass it. Human perception, product semantics and human preference work as a circle and influence the human to recognize objects.

Because human preference works in large part to influence the human understanding the things, we need to also figure out a way apply this part to analysis of the line features. And in the second part of chapter three we divided the line features into two parts; first one is the physical line features which can be detected by the human sensory system directly, such as the line shape, and the second one is the symbol line feature, which is produced by the human perception and invisible. And the human also will produce the different preferences towards those two different line features.

3.3.1 Human Preference of The Physical Line Features

For the physical line features such as line shape, humans also have their own preference towards it.

As we discussed above, the human has the natural behavior and preference towards item shapes. If the shape has a sharp transition contour, it will deliver a threatening feeling, which will cause a negative preference towards it. Meanwhile, the shape with rounded transition contour can also deliver a safe and touchable feeling to users and attract people to make contact with it, such as people like touching the soft rounded surface because it's delivering a feeling of comfort and safety. According to this human nature, we can apply to this rule to line design when we analye the line shape drawings. In order to apply this rule to the analysis process, we also need to combine the “description” of that line part.

For the line shape feature, there are two parts which are needed to analyze; first is the shape of lines and another is the curvedness level of lines. There are three different shapes of lines, straight line, concave line and convex line, and all of them can let people produce the different preferences towards them. As we discussed in the literature review, in order to judge the shape of the line, we have to put the line shape drawings into the Coordinate system.

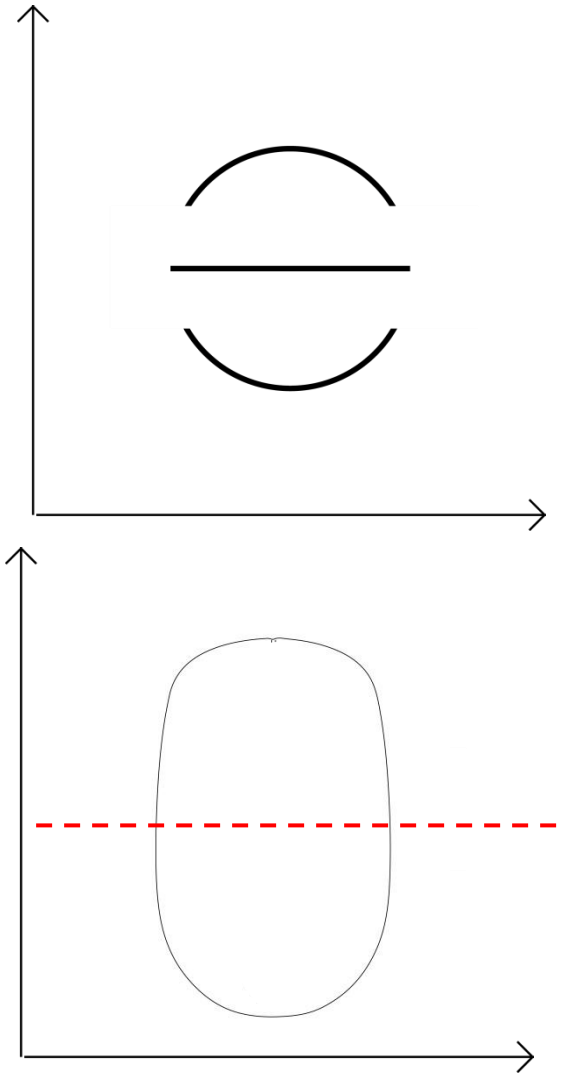


Figure 36 Lines in Coordinate system

Putting a product line drawing into the Coordinate system and put a line in the middle of the drawings (see Figure 36) is an easy method to figure out what part is concave line and which part is convex line. In the literature review, we found out that concave line is regarded as the smile-like line, which can deliver the positive emotion to humans; meanwhile convex line looks like the frown-like line and can deliver the negative emotion to humans.

When we judge the lines in the product, we need to figure out the description of the lines and classify the emotion it should deliver; if it's close to the negative emotion, a designer can

apply the convex lines and if it represents the positive emotion, the designer can use the concave lines.

For the curvedness part, we can analyze the “description” of lines to judge if it fits the feelings it delivers. Such as when the description of this line is contour line, for a handle part of the tool, it needs to deliver comfortable feelings to humans. It requires low curvedness line features and no sharp transition design. And when the description of the line is function line, dangerous for touching, which means human can't touch it and need to stay away, it will require a high curvedness line feature design.

We can use the human preference towards the curvedness of line and the “description” requirement of lines to determine the line feelings and judge if its curvedness fits or not.

3.3.2 Human Preference of the Symbol Line Features

The humans don't only have the preference towards the physical line features, but they also have the preference towards symbol line features. When they recognize the items, beside the basic physical features such as the shape, length, their perception also will tell them the meanings of the items and what items represent. The human also will produce preferences towards the suppositional things that they understand.

For example, from the picture, the first patten is just three circle lines which share the same center points from the physical line feature view. But after the perception of the human, human can link it to the line drawing view of a button which shown below. And the second patten is only different circular lines which also share the same center points from the physical line feature views, but it also can be regarded as the line drawing view of a button and this button can also be rotated (see Figure 37). Human perception gives the line drawing view different

meanings. Then people will produce the preference towards the shape of button, not only towards the line shapes, according to the understanding of those meanings behind the lines.

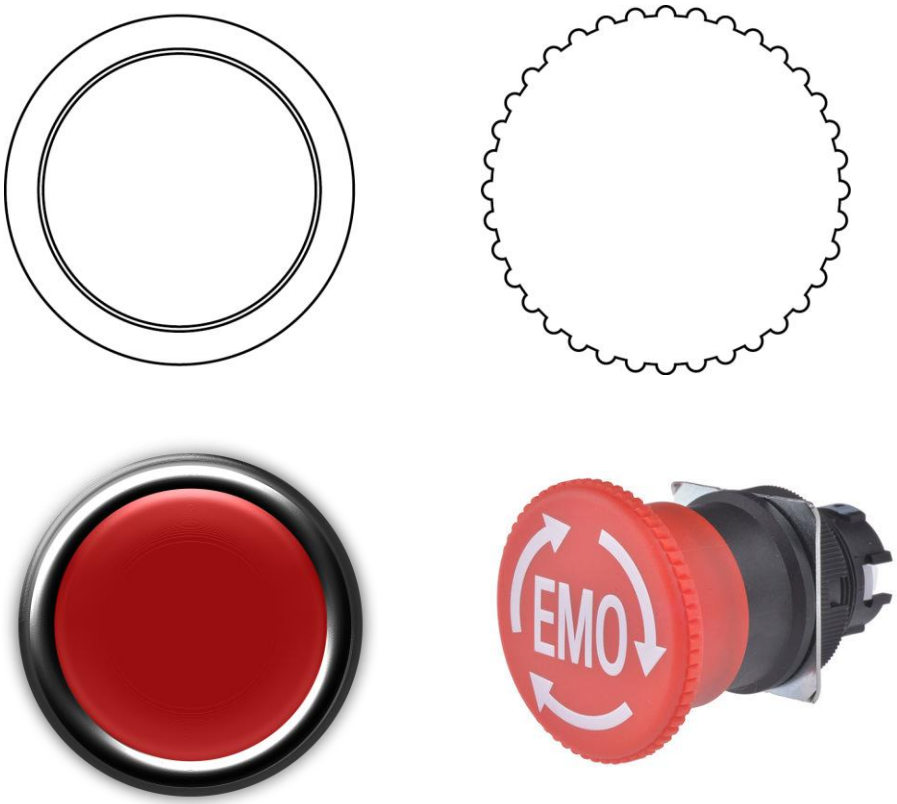


Figure 37 Buttons

When we judge the lines, we need to figure out the meanings they deliver to the humans. The meanings they deliver can include much information, such as what symbol meaning the lines represent, what it looks like and so on. Then, according to the different meanings and symbol the lines represent, designer can judge what kind of preference human may produce, negative or positive.

3.4 Summarize The Guideline Steps

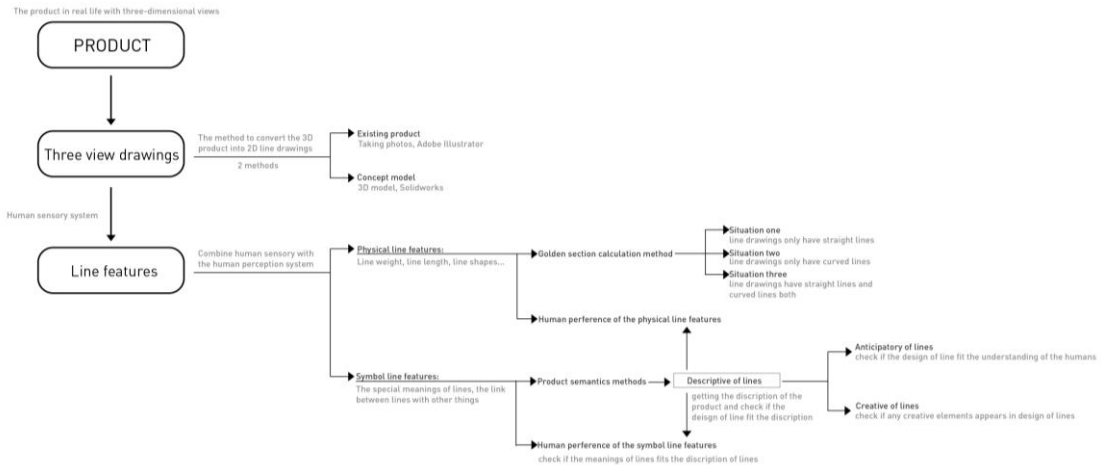


Figure 38 Whole process of the guideline

Figure 38 shows the whole process of the guideline. This guideline provide a method which can judge and refine the line shape. The details summary steps as follow:

1. Find a product you want to analyze.

2. Get the line shape drawing based on the product type. If it is an existing product, take photo of it and use *Adobe Illustrator* to get the line shape drawing, and if it is a concept model, use *Solidwork* to get the line shape drawing.

3. Get the line features and divide those features into two categories: physical line features and symbol line features.

4. Use the Golden ratio calculation method to calculate the physical line features.

5. Analyze the result and figure out which part of line that need to be refined.

6. Refine the shape of line.

7. Analyze the line shape drawing based on three methods of product semantics: descriptive, anticipatory and creativity. Get a description of the product.

8. Analyze the human preference of the physical line features based on description of the product.

9. Analyze the human preference of the symbol line features based on description of the product.

Chapter Four

An Application of the Design Guideline

Because our main purpose of this thesis is refining the appearance of the products based on analysis the line shape of product in a two-dimensional view, I need to use one existing product as an example to analyze and refine. According to the suggestion from my professor, we decided to apply my guideline to a mouse. The benefits of using the mouse as an example to apply my guideline as follows:

- Because the mouse works as an accessory part of the computer, the function of it is simple: a handheld pointing device which can locate a cursor on a computer screen. Therefore the function area of the mouse is simple; it only requires left click and right click buttons, one roller, and the bottom detector to interpret the motion and movement of the mouse. Those functions are the main features of a mouse. The simple function of the mouse can reduce the influence on the appearance of the mouse.

- The second benefit of the mouse is its simple shape. The mouse is a simple tool for a computer which means the decoration is not its main function. So the shape of the mouse is simple and easy to calculate. And also it is a handheld tool which means its size is small.

- Computer is one of the most necessary tools in our daily life. It is impossible to imagine that we live and deal with things without a computer. It's almost become an electronic device which used by everyone in everyday regardless the age of users or the area it works. The mouse, as one necessary accessory of the computer, also has a high demand in the market. Therefore, analyzing the mouse is meaningful.

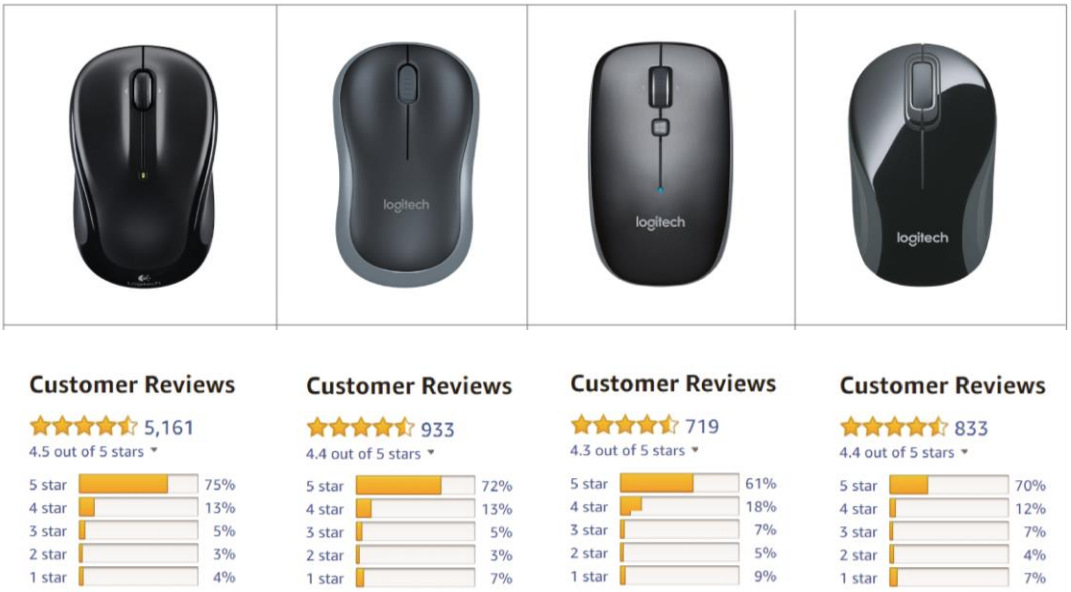


Table 8 Customer review of mice

In Chapter Three, we analyzed four Logitech mice, which are sold on the Amazon.com website (see Table 8). Those four mice have different customer reviews listed on that website. From those reviews, we can tell the third one is the least popular one among these four mice. Therefore, I will pick up the third one to apply the guideline and refine its appearance based on analyzing its line shape in a two-dimensional view. The third one is Logitech Bluetooth Mouse M557 (see Figure 39).

Figure 39 Logitech Bluetooth Mouse M557

4.1 Get the Line Features of the Mouse

4.1.1 Get the Line Shape Drawing of the Mouse

Because we need to analyze the line shape of this mouse to refine its appearance, the first step is getting the line shape drawings of it according to the guideline I discussed in Chapter Three.

The third mouse is an existing product; therefore, what we need is taking the photo of the mouse and then dragging this photo to the software *Adobe Illustrator*. Using commands “Image trace”, “make and expand” and “pen” to get the line shape drawing (see Figure 40) of the mouse.

Figure 40 Line shape of the mouse M557

4.1.2 Catch the Line Features of the Mouse According to Human Sensory System

After getting the line shape drawings from the software *Adobe Illustrator*, the next step is getting the line features of this mouse according to the human sensory system.

From the line shape drawing, we can recognize the line features like the line curvedness and line length. The main line shape of the mouse can be divided into two parts: the first part is

the outside outline of the mouse, the main shape of the mouse, and the second part is the line that belongs to the function area (see Figure 41).

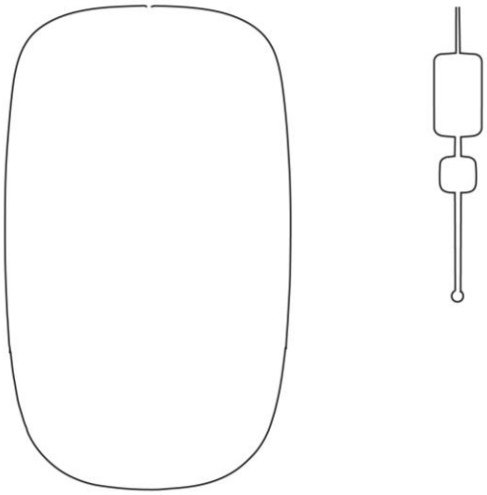


Figure 41 Two parts of line shape

The first part of the line shape is made of the symmetrical curved line and does not have any straight lines. Also, we can know the curvedness of this curved line is rounded, with no sharp edges.

The second part of the line shape is made of the curved lines and straight lines, and its structure is symmetrical also. The curved line shows up in the corner of the straight lines.

4.1.3 Catch the Line Features of the Mouse According to Human Perception

From the human sensory system, we can understand the basic shape and features of the mouse from the line shape drawing. But when the humans see the line shape drawings, they do not only just understand the basic features of it, they can also tell the information behind the lines. Such as when they see the second part drawings (see Figure 42), they can understand the "holes" in the line shape drawings means the functional area based on their perception's understanding.

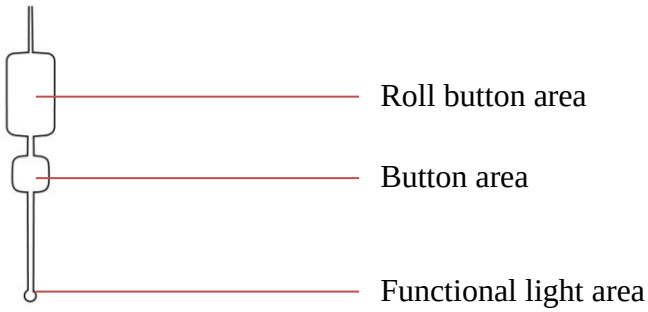


Figure 42 Second part of line shape drawing

When we see the picture of the inner line shape drawing, the shape of it also can remind us of the shape of the water drop (see Figure 43). There are some similar points between the line shape of the inner part and the water drop. Humans may produce the associated imagining when seeing the inner line shape drawing.

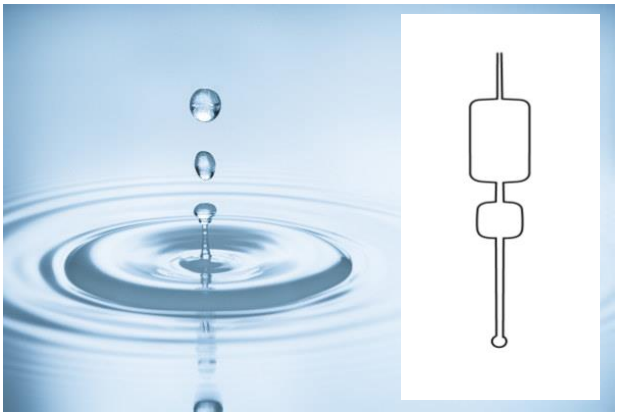


Figure 43 Water drops

Here is the summary of the line shape features of the mouse:

Physical line features:

- The outer part of line shape drawing is made of curved lines, and the inner part is made of curved line and straight lines.
- The curvedness of curved line is rounded, not sharp.
- Line length can be detected by the eyes.

Symbol line features:

- The inner line shape drawing contains the functional area. The functional area is made of squares with soft corners. The outer line shape drawing represents the main shape of the mouse, and the lines in there work as decoration lines.

- There are some special links between the inner line shape drawings and other aspects. When it looks like the water drop falling into the water, the image may deliver some special social message to the human.

4.2 Calculate the Line Features of the Mouse

Once we get the physical line features and symbol line features of the mouse, I need to calculate those features according to the guideline I came up with in Chapter Three. I divided this calculation process into two parts: first part is calculating physical line features and the second part is calculating the symbol line features.

4.2.1 Calculate the Physical Line Features of the Mouse

4.2.1.1 Golden Ratio Calculation Method

According to the analysis of line features of the mouse, for the physical line feature, I need to calculate the outer line shape drawing first. Because the outer line shape drawing represents the main shape of the mouse, the main function of it is decorative and the inner line shape drawing represents the main function area of the mouse. This factor will influence the line design of the inner line shape.

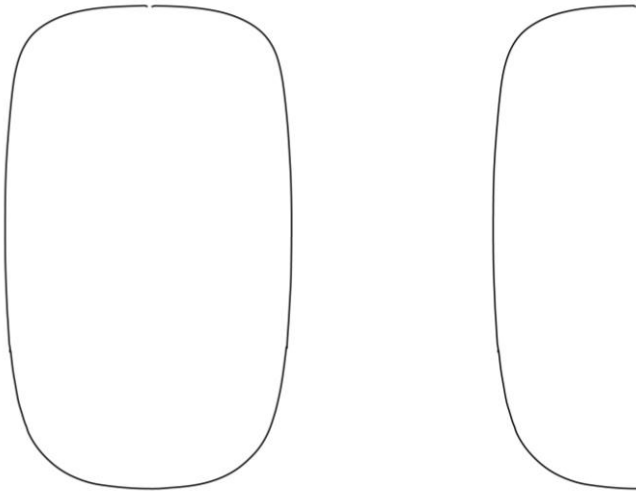


Figure 44 Outer line shape

Based on the steps in the guideline, I cut the outer line shape in half (see Figure 44) because of its symmetrical structure. Then I started to calculate that curved line and get pictures as follows (see Figure 45 and Figure 46):

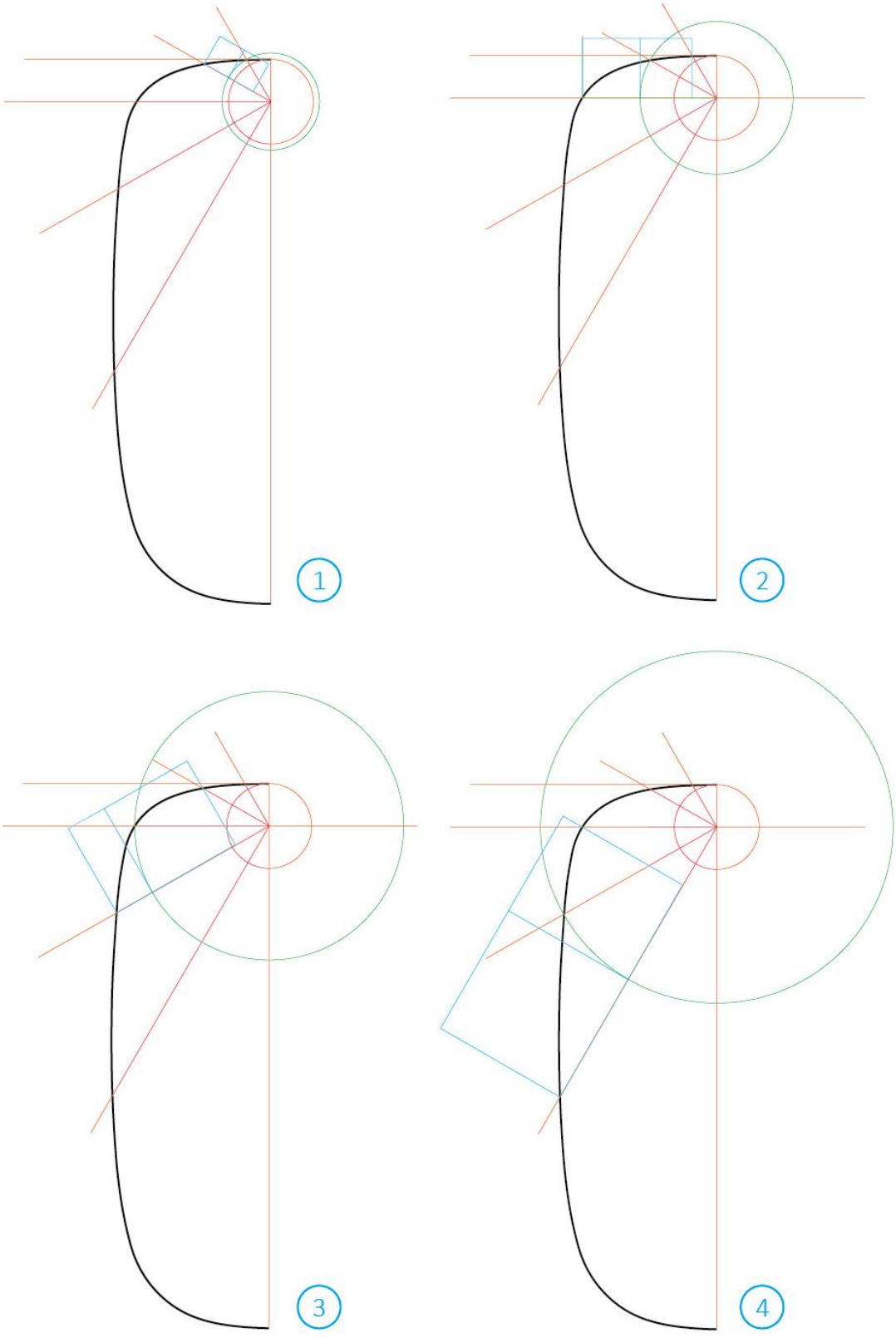


Figure 45 Calculate the curved line

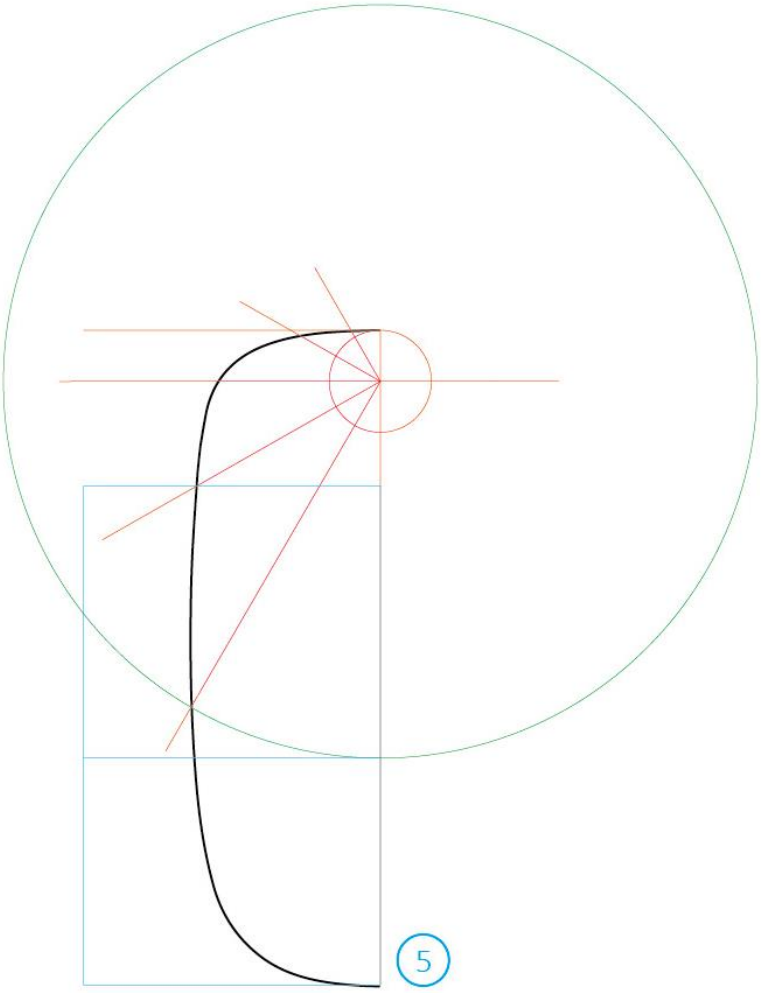


Figure 46 Calculate the curved line-2

After finishing the calculating of the curved line in mouse, we can get five blue squares which are shown below (see Figure 47 and Figure 48). Then I need to measure the dimension of the edge in each square.

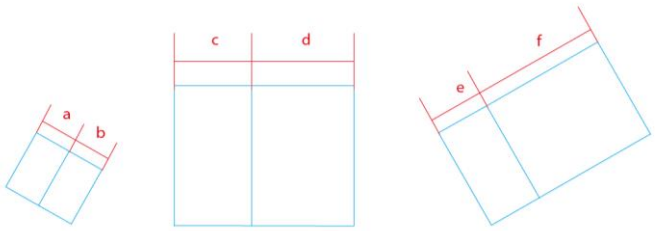


Figure 47 Squares of the curved line

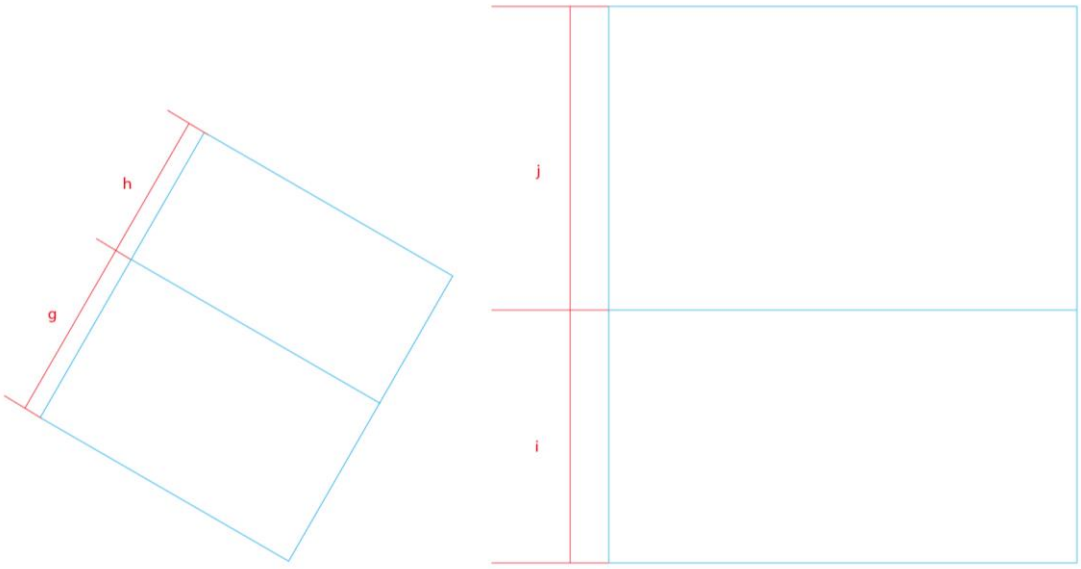


Figure 48 Squares of the curved line-2

a = 0.19” b = 0.2” c = 0.28” d = 0.66’’ e = 0.42” f = 0.61” g = 0.94” h = 0.74” i = 1.3” j = 1.55”

The dimensions I list above are the dimensions of the edges in the blue squares, and then I need to calculate those dimension sizes and compare the results with the Golden ratio.

b/a= 1.05 (1.618-1.05= *0.568*)

d/c= 2.35 (1.618-2.335= *-0.732*)

f/e= 1.45 (1.618-1.45= *0.168*)

g/h= 1.27 (1.618-1.27= *0.348*)

j/i= 1.19 (1.618-1.19= *0.428*)

Compared with the Golden ratio, we can get the result which line segment is close to Golden ratio line and which one is not. Apparently, the CE line segment is closer to the Golden ratio line, and AC and EG line segments need to be refined.

4.2.1.2 Human Preference of the Physical Line Features of the Mouse

In product semantics theory, there are three methods to improve the understanding level of a product. It is “descriptive”, “anticipatory” and “creative”. In this analysis section, we need to figure out what is the “descriptive” part of this mouse, what is the “anticipatory” part of this mouse and what is the “creative” part of this mouse.

First, the description of the mouse is “a handheld small electrical device”. The handheld feature requires the appearance of the mouse being rounded and not sharp because a rounded curve will deliver the safe and comfortable feelings to humans and make them like to touch the mouse.

Second, the anticipation of the mouse requires this mouse having the correct functions. Based on the human understanding, the functional areas, such as the right click and left click button and scroll wheel, should be in the middle of the mouse.

Third, the creativity of a mouse means some part of the design is outside of people’s anticipation and surprises the users. Putting the scroll wheel on the left side of the mouse is out of expectation of users, so we can call it a creative design.

According to the line shape drawing of the mouse, we can tell the basic appearance of this mouse is rounded and without sharp corners. It basically fits the description of the “handheld” feature. Therefore, we do not need to change this feature because it already can deliver safe and comfortable feelings to the users. The human preference of the physical line features can count as “positive”.

4.2.2 Calculate the Symbol Line Features of the Mouse

When the users link the inner line shape of the mouse with the water drop, what kind of feelings they will produce? The reason why the user will produce this link is there are three hole

shapes in the inner line shape drawings. Those three items are in a line, which make them look like many water drops falling from the air.

Figure 49 Water drop pictures

Usually the human feeling of the water is soft, clean, tolerance. And we also regard the water as the resource for the life (see Figure 49). Green and blue colors are the main color of the water. According to those records of the water and water drop, we can assume the symbol line feature can deliver positive feelings to humans. The human preference of this symbol line feature is positive. Therefore, we need to enhance the line feature.

4.3 Refine Design of the Line Shape of the Mouse

According to the method of Golden ratio line, I calculate the outer curved line have to across three points to refine the shape of the curved line. The picture is shown below (see Figure 50) :

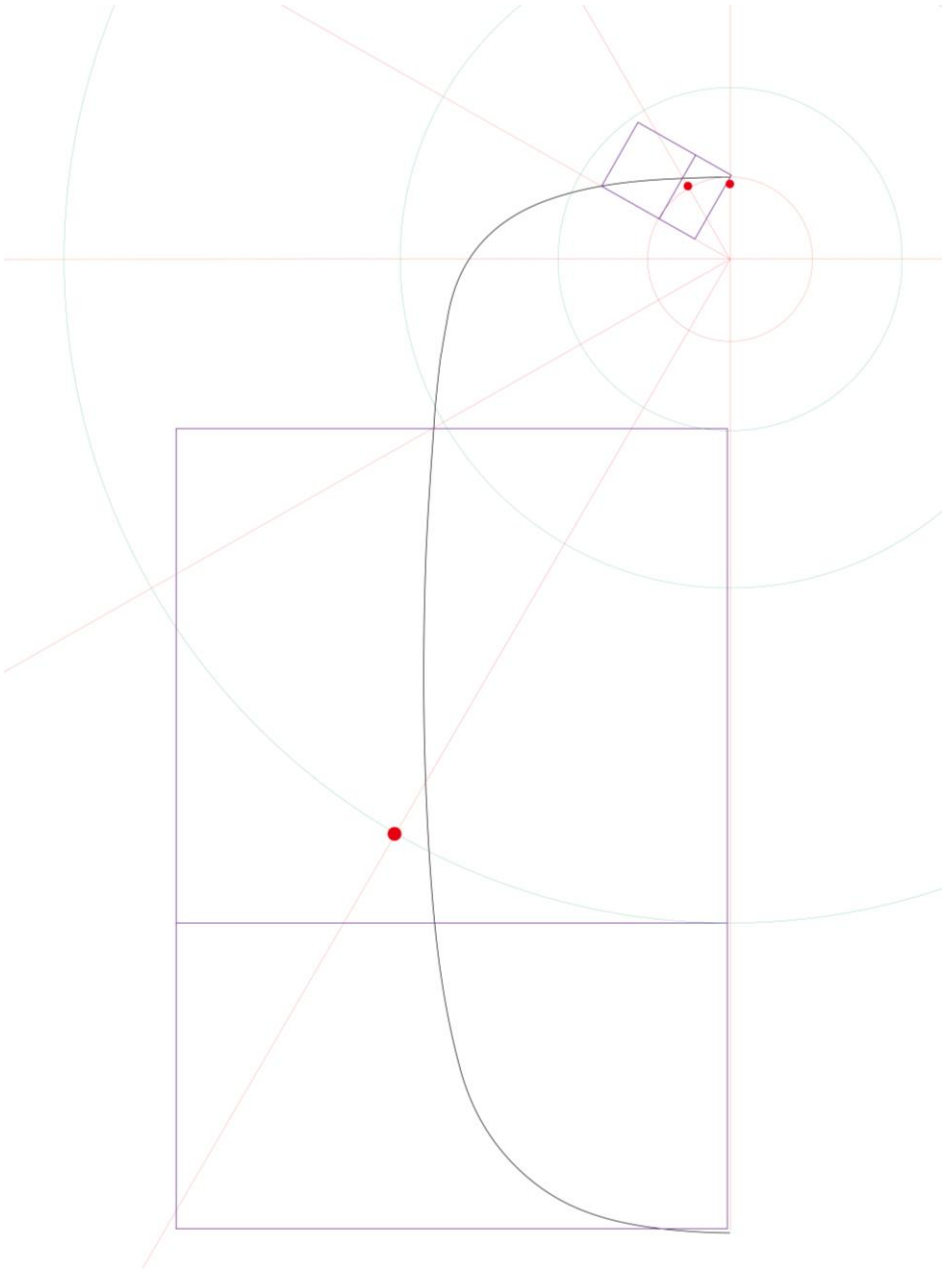


Figure 50 Refined curved line

We can tell from the picture, these three red points in the drawings are the key points of the curved line which fit the Golden ratio. I need to redesign the outer curved line across these three red points. Based on these three points, I created a new curved line shape shown as follows (see Figure 51):

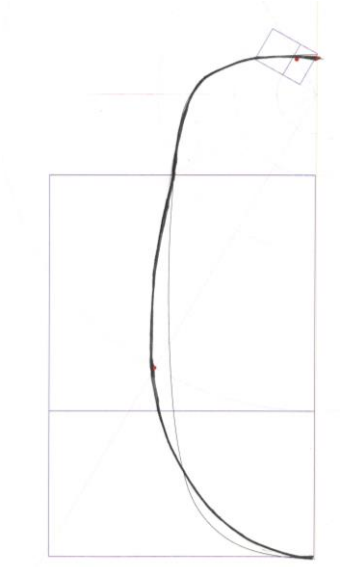


Figure 51 Sketch of curved line

Then we can input this curved line picture into the software *Adobe Illustrator* to get the whole top view shape of the mouse (see Figure 52).

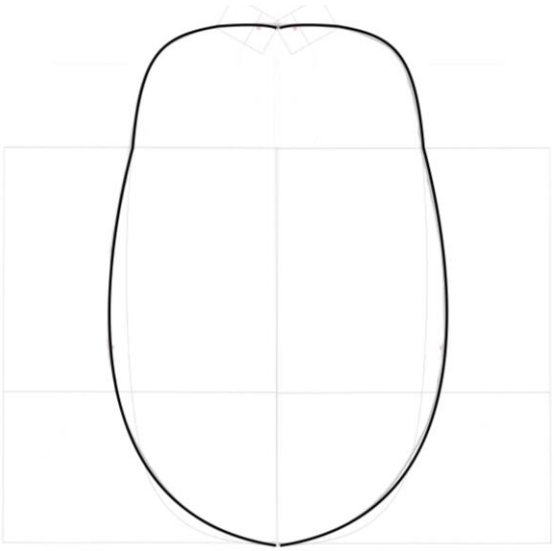


Figure 52 Refined curved line of mouse

According to the refined top view of the outer curved line shape, we can start using materials to craft a one-to-one scale physical model and compare it with the original mouse shape. The steps are as follows:

Figure 53 FormCore model of mouse

Step one: Put the refined top view drawing on the FormCore board, then cut the board. (See Figure 53)

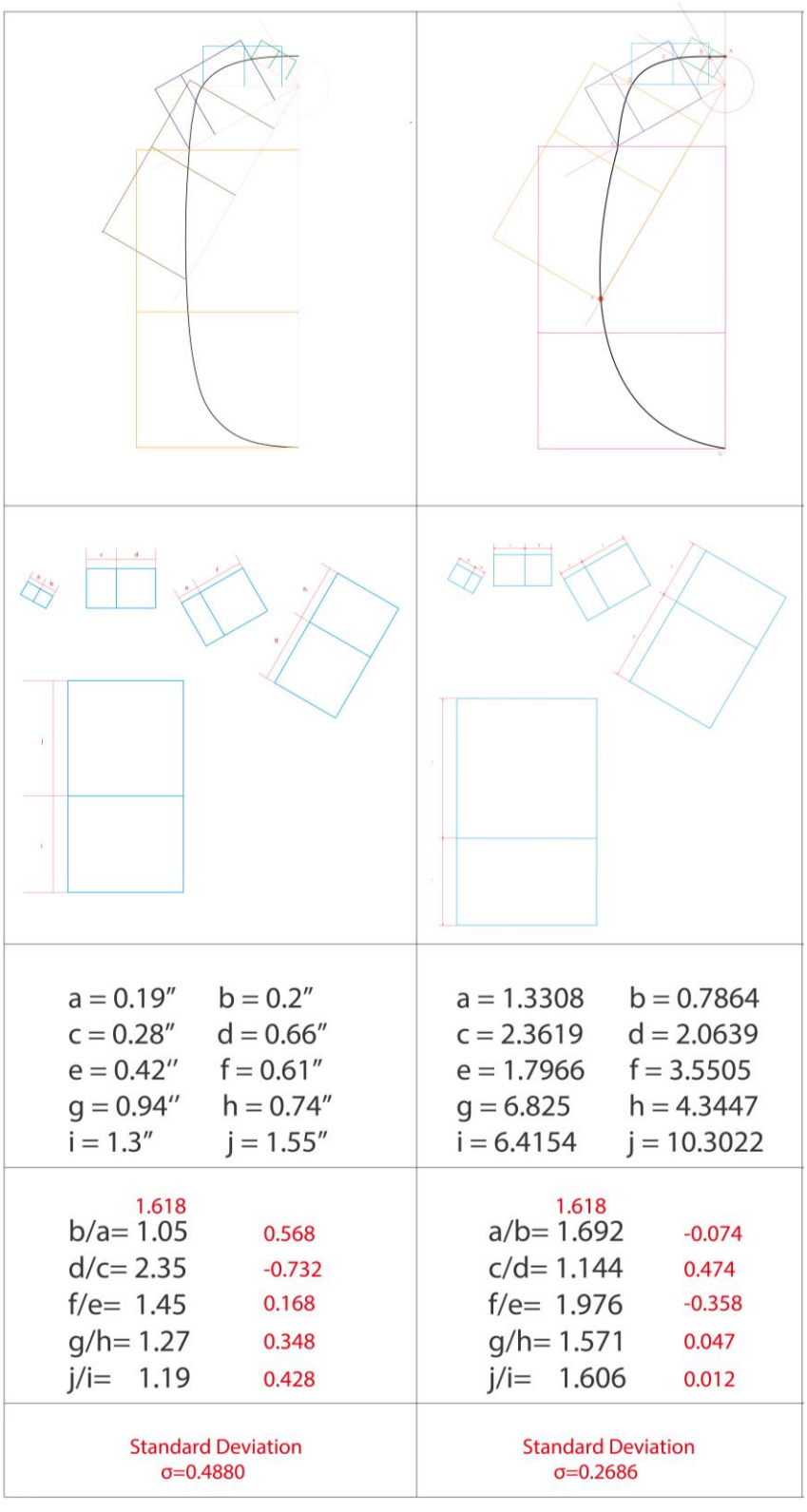
Step two: Sand the FormCore board according to the refined top view of the mouse.

Step three: Refine the mouse shape based on the side view of the mouse (See Figure 52).

Step four: Sand the rough model of the mouse and then paint it (see Figure 54).

Figure 54 Refined mouse and original mouse

After getting the physical FormCore refined curved line model, we can compare the appearance of this mouse model with the original mouse and do some calculation.



a = 0.19″ b = 0.2″ c = 0.28″ d = 0.66″ e = 0.42″ f = 0.61″ g = 0.94″ h = 0.74″ i = 1.3″ j = 1.55″	a = 1.3308 b = 0.7864 c = 2.3619 d = 2.0639 e = 1.7966 f = 3.5505 g = 6.825 h = 4.3447 i = 6.4154 j = 10.3022
1.618 b/a= 1.05 0.568 d/c= 2.35 -0.732 f/e= 1.45 0.168 g/h= 1.27 0.348 j/i= 1.19 0.428	1.618 a/b= 1.692 -0.074 c/d= 1.144 0.474 f/e= 1.976 -0.358 g/h= 1.571 0.047 j/i= 1.606 0.012
Standard Deviation σ=0.4880	Standard Deviation σ=0.2686

Table 9 The comparative result between two shapes

As Table 9 shows, the second lines have smaller standard deviations which means it is more similar to the Golden ratio line. It means the refinement of the curved line shape works. And also I did the similar the calculation which parts of refined curved line fit the Golden ratio square well.

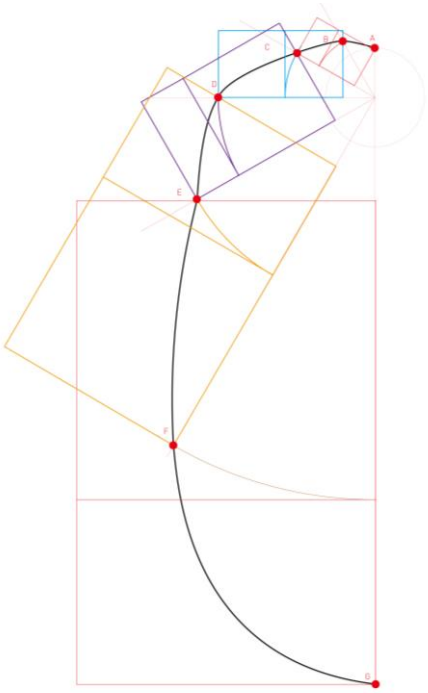
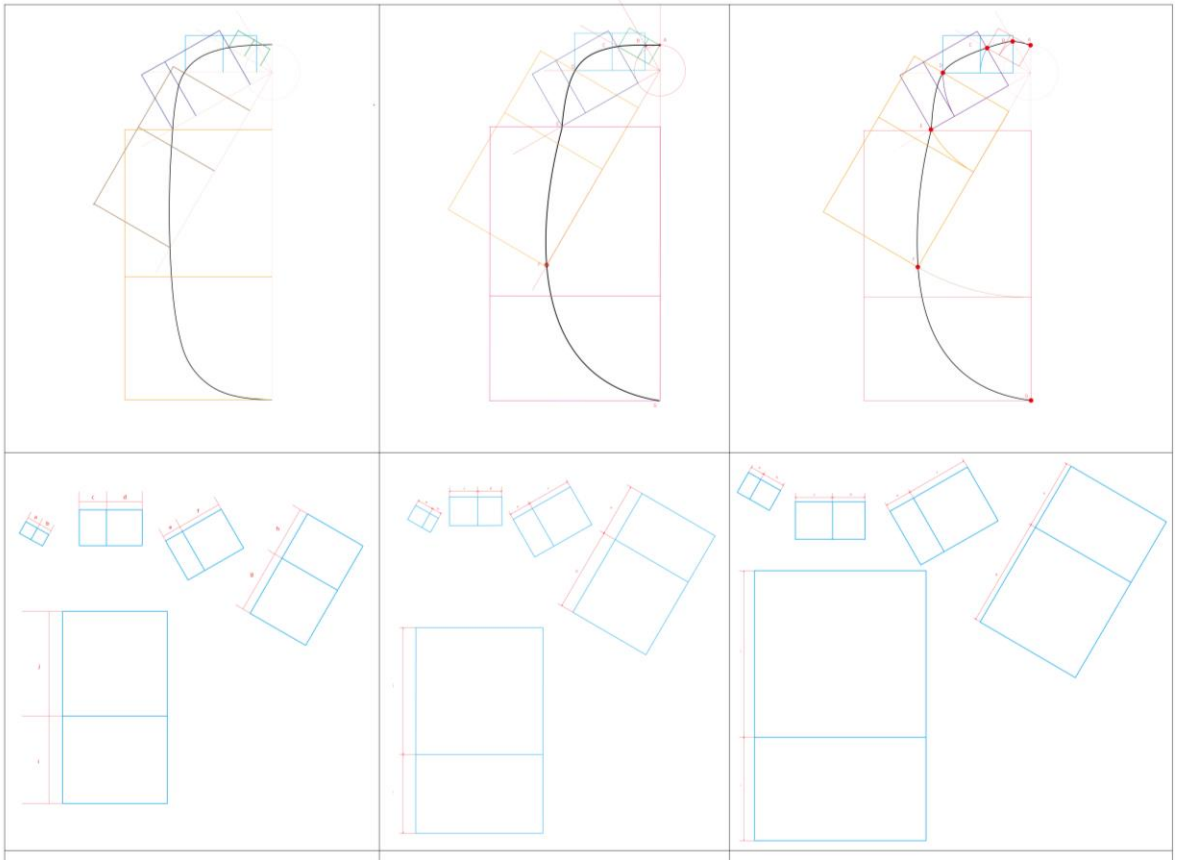


Figure 55 The second refined curved line

As Table 10 shows, compared with another two shape, the third one has the smallest standard deviation which means its shape is closest to the Golden ratio curve. It also means the refinement of the curved line shape works in the second refined curved line.



a = 0.19″ b = 0.2″ c = 0.28″ d = 0.66″ e = 0.42″ f = 0.61″ g = 0.94″ h = 0.74″ i = 1.3″ j = 1.55″	a = 1.3308 b = 0.7864 c = 2.3619 d = 2.0639 e = 1.7966 f = 3.5505 g = 6.825 h = 4.3447 i = 6.4154 j = 10.3022	a = 1.4366 b = 0.8879 c = 2.3619 d = 2.0418 e = 1.7966 f = 3.5505 g = 6.9092 h = 4.3447 i = 6.5093 j = 10.5329
1.618 b/a= 1.05 0.568 d/c= 2.35 -0.732 f/e= 1.45 0.168 g/h= 1.27 0.348 j/i= 1.19 0.428	1.618 a/b= 1.692 -0.074 c/d= 1.144 0.474 f/e= 1.976 -0.358 g/h= 1.571 0.047 j/i= 1.606 0.012	1.618 a/b= 1.618 0 c/d= 1.157 0.461 f/e= 1.976 -0.358 g/h= 1.590 0.028 j/i= 1.618 0
Standard Deviation σ=0.4880	Standard Deviation σ=0.2686	Standard Deviation σ=0.2613

Table 10 The comparative result between three shapes

Chapter Five

Conclusions and Suggestions for Future Study

The objective of this thesis is to propose design guidelines to analyze the line shape drawings of the product in two-dimensional views, and then, according to the analysis results, refine the appearance of the product. The purpose of the guidelines is to provide with a method to analyze the line shape drawings and refine the appearance of the product based on a two-dimensional view for the designer.

The research starts with figuring out three main questions: how does human recognize the world and product base on analyzing the human sensory system and human perception; how to make the product more understandable and beautiful based on analyzing the product semantics; and what is the human preference of the line shape of products? Based on understanding these three questions, we just need to figure out the relationship between these three parts, and then apply this relationship to analyze the lines of product. Thus the design guidelines were created, and the sample of work is designed to demonstrate the application of the design guideline.

There are still more aspects that can be further investigated in the next phase. Suggestions for the further research as follows:

1. The guideline only showed how to analyze the line shape drawings of product in top views. This guideline also can be used for analyzing any angle views of the product such as the side view, the bottom view, the front view or even the forty five degree views. The more views we are analyzing, the more correct the result.

2. Because people may have the different preference based on their different culture, experience and the place they live, for the future study, this research may focus on analyzing some details of the human preference based on their culture or the location.

3. This research only studies the simple product with the simple line shape and functions. The designer can further investigate the application of this guideline to a complex product which has more complex line shape and more functions.

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