Mechanical Hands

VM250 Design and Manufacturing I

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Prepared by:

Chu Bei
Huang Jianchi
Liu Hanyang
Shen Junjie
Shen Yang
Undergraduate Mechanical Engineering Students
UM-SJTU Joint Institute
Team 14

Prepared for:

Dr. Li Mian
Associate Professor, VM250 Instructor
UM-SJTU Joint Institute

Abstract

The mechanical hands built by our team are completely designed and manufactured on our own. They are made of various kinds of raw materials bought from TaoBao and market. CAD works are drawn, and later laser cutter is used to manufacture every component. The mechanical hands are made of Acrylic (PMMA) board. PVC pipes are employed to build the mechanical arms. In order to grip and manipulate knots conveniently, we simulate the translocation of the knots and then decide to design our prototype with three freedoms, which are open and shut mode, tilting mode and rotation mode. Kite string is used to translate tension, and finally controls the open and shut of the hands, as well as the tilting mode. Besides, the gears used to rotate the mechanical hands about their respective central axis make the rotation operation convenient. The mechanical hands can pick up thread precisely and do various movements easily. We test and calculate the precision of each component again and again to make the transmission as smooth as possible. We are confident to use our hand-made mechanical hands to tie any knots as required.

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1. INRODUCTION

Mechanical hands are extensively applied in industrial manufacturing. With modern technology, mechanical hands can be produced rapidly, with high accuracy. The mechanical hands will not go wrong unless the program is damaged. Hence, the application of mechanical hands greatly improves production efficiency as well as reduces the cost.

2. PRODUCT DESIGN

This section provides details about our product design of mechanical hands. It is comprised of three main parts, Problem Definition, Concept Generation and Concept Selection.

2.1 Problem Definition

2.1.1 Customer Requirements

1. Light Weight : at most 2.20 lb each
2. Reasonable Size : 1.3 m long
3. Reasonable Driving Force : at most 2.25 lb
4. Clamp the Rope : friction supplied by clamp is at least 1.12 lb
5. Low Cost : at most $80

2.1.2 Engineering Specifications

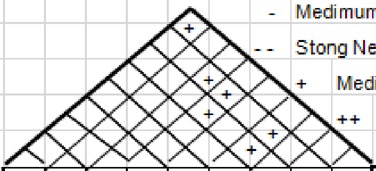
1. Rotating Angle (°)
2. Friction Coefficient (lb/lb)
3. Force (lb)
4. Moment (lb*ft)
5. Effective Spring Constant (lb/ft)
6. Length (ft)

7. Weight (lb)
8. Maximum Deflection (in)
9. Cost ($)

2.1.3 Quality Function Deployment

In order to translate qualitative customer requirements to quantitative engineering specifications, a tool for design problem definition is needed. In a QFD, customer requirements are on the left part and engineering specifications are on the upper part while the middle matrix is the correlation for requirements and specifications. There are also two benchmarks during the brainstorm. For the benchmarks section, “5” means “satisfies perfectly”, while “4” equals to “satisfies mostly”, “3” to “satisfies somewhat”, “2” to “satisfies slightly”, and “1” refers to “does not satisfy at all”. Our product is competitor A, B and C.

Analyze the QFD below, we can know that clamp the rope tightly is the first issue we should pay efforts to. Besides, reasonable driving force and lasting for a long time are also important.



- Medimum Negative
-- Stong Negative
\+ Medimum Positive
++ Stong Positive

Benchmarks

	Weight (1-10)	rotating angle	friction coefficient	force	moment	effective spring constant	length	weight	max. defelction	cost	*competitor A*	*competitor B*
looks good	3						9	3			5	2
light weight	6							9			4	4
handle comfortably	7				9			3			2	2
reasonable size	5						9				3	5
reasonable driving force	9	1	1	9	3	9					2	2
clamp the rope	10		9			9					3	4
inexpensive	4									9	1	3
last for a long time	8		3						9		3	4
Measurement Unit		.	/	lb	lb*ft	lb/ft	ft	lb	in	$		
Target Value												
Total		9	123	81	90	171	72	84	72	36		
Normalized		0.01	0.17	0.11	0.12	0.23	0.10	0.11	0.10	0.05		
competitor A												
competietor B												

Competitive benchmarks
5 = satisfies perfectly
4 = satisfies “mostly”
3 = satisfies “somewhat”
2 = satisfies “slightly”
1 = doesn't satisfy at all

Correlation between customer reqs and eng. Specs
9 = Strong Relationship
3 = Medium Relationship
1 = Small Relationship
(blank) = Not Related

Table 2.1 QFD of the mechanical hands.

2.1.4 Product Design Specifications

Items	Detailed Specifications
Performance	● Should finish many types of knots at 1.2 m ● Should be one-man operated ● Should be handheld ones
Size	1.10 m (length) * 0.6 m (width)
Weight	0.416 kg each
Cost	￥92
Product Life Span	At least one year
Material	● Plastic ● Rubber ● Steel
Driving force	No more than 10 N
Safety	● Avoid sharp corner, all edges should be polished smooth ● Surface should be polished smoothly

Table 2.2 PDS of the mechanical hands.

2.2 Concept Generation

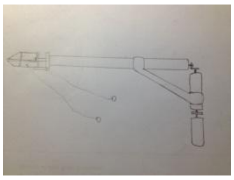
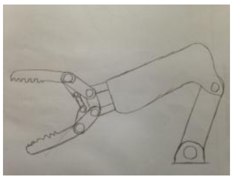
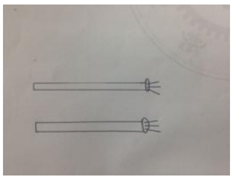
2.2.1 Brainstorm

Mechanical hands are used in the situation that human cannot get hands onto the objects directly to operate them. This project require us to design a simple mechanical hands which can tie and unties some specific types of knots.

We first divide our design into two parts. One is to determine how many DOF for each hand. We finally decide that the mechanical hands should have three functions, opening and shutting, tilting and rotating. Then, we discuss how to realize these functions. String is our first choice as control device, but the design is complicated and it is also hard to manufacture. So we change it to the rubber band.

The other important thing is to design the gearing so that our mechanical hand can rotate about its central axis. The key part is to determine how to connect the shaft to the mechanical hand. We cannot use a complex structure due to our limited ability to manufacture, so a simple way we come up with is to use a shaft whose cross section is hexagon, and then cut a hexagon hole on the bottom of the bottom of the mechanical hand.

2.2.2 Pugh Chart

CR	Weight	 Design 1	 Design 2	 Design 3
Looks good	3	S	S	-
Light weight	6	S	-	+
Handle comfortably	7	S	-	S
Reasonable size	5	S	-	S
Reasonable driving force	9	S	-	S
Clamp rope	10	S	S	-
Inexpensive	4	S	-	+
Last long	8	S	+	S
	Total +	0	+1	+2
	Total -	0	-5	-2
	Total	0	-4	0
	Weighted total	0	-23	-3

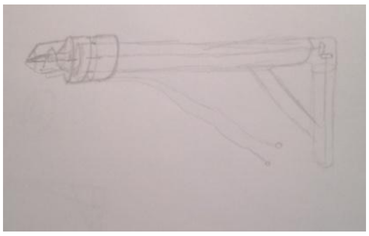
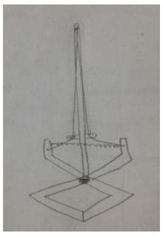
CR	Weight	 Design 4	 Design 5
Looks good	3	+	S
Light weight	6	S	S
Handle comfortably	7	S	S
Reasonable size	5	S	S
Reasonable driving force	9	S	-
Clamp rope	10	+	-
Inexpensive	4	S	S
Last long	8	S	S
	Total +	+2	0
	Total -	0	-2
	Total	+2	-2
	Weighted total	+13	-19

Table 2.3 Pugh chart of the mechanical hands.

According to the Pugh chart, we select concept design 4 as our final design.

2.3 Concept Selection

2.3.1 Final Design Selection

Figure 2.1 demonstrates our final prototype, based on concept design 4. As can be seen, each consists of two main parts, mechanical hand (Figure 2.2) and mechanical arm (Figure 2.3). The mechanical hand has three freedoms, corresponding to three operation modes, open and shut, tilt and rotation.

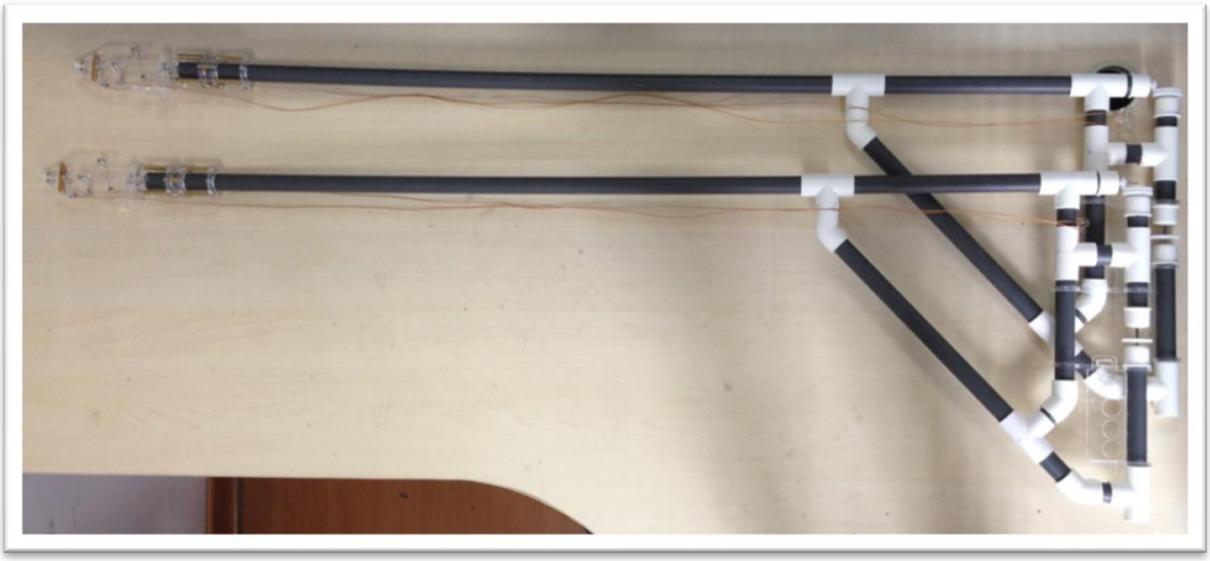


Figure 2.1 Final Prototype.

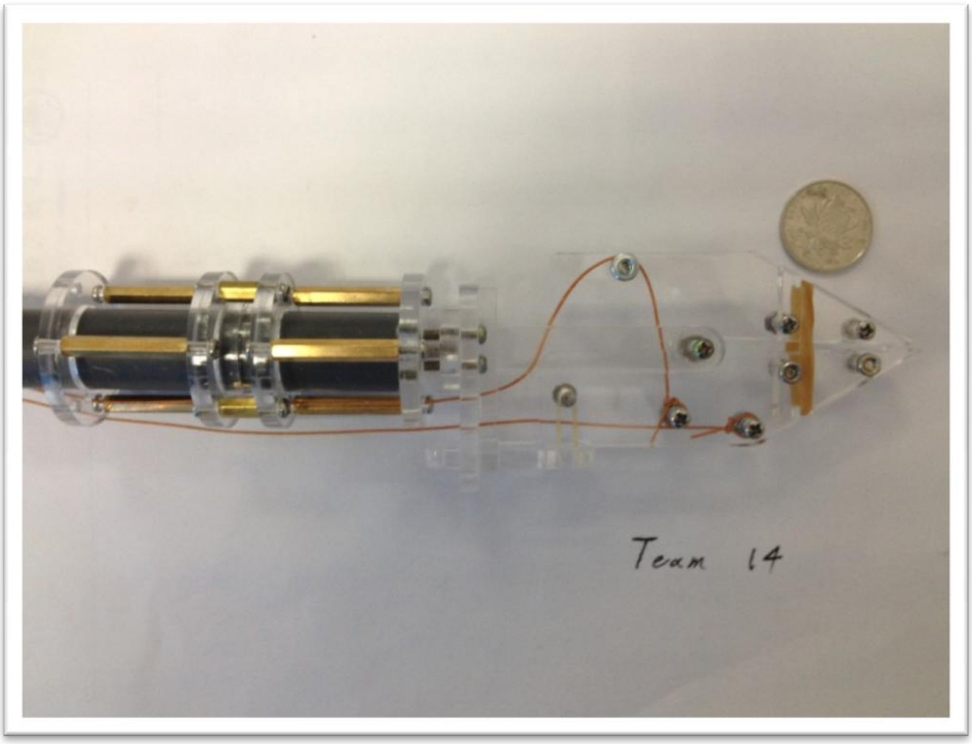


Figure 2.2 Mechanical hand.

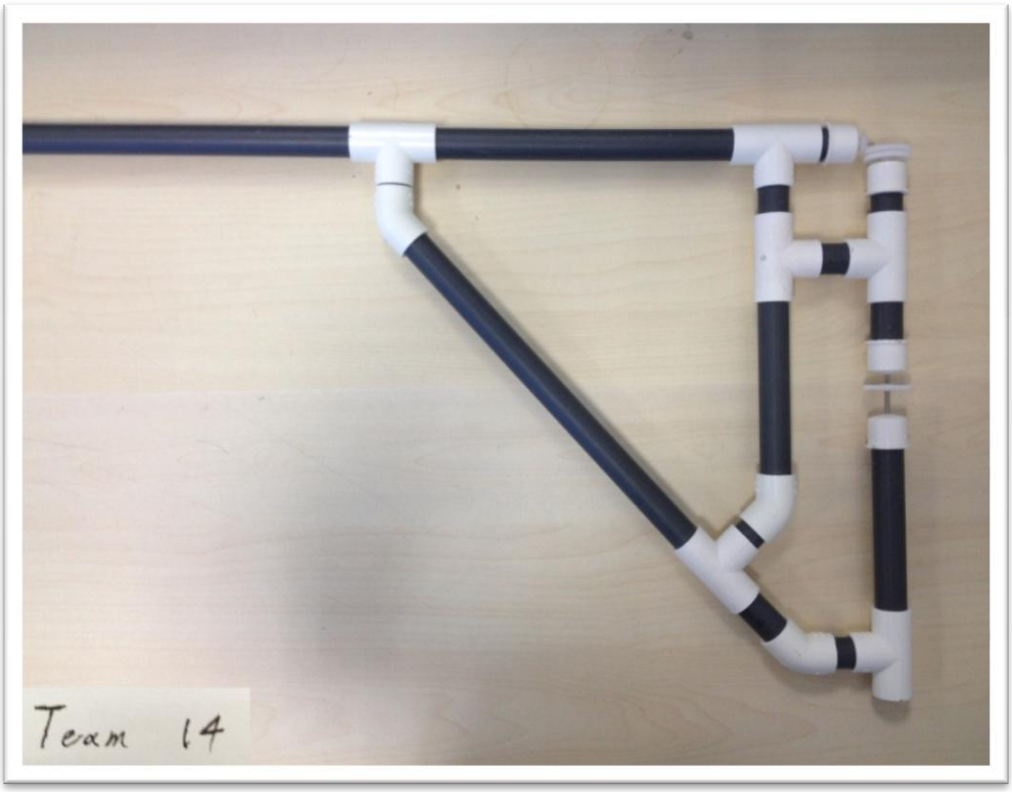


Figure 2.3 Mechanical arm.

2.3.2 UG Works

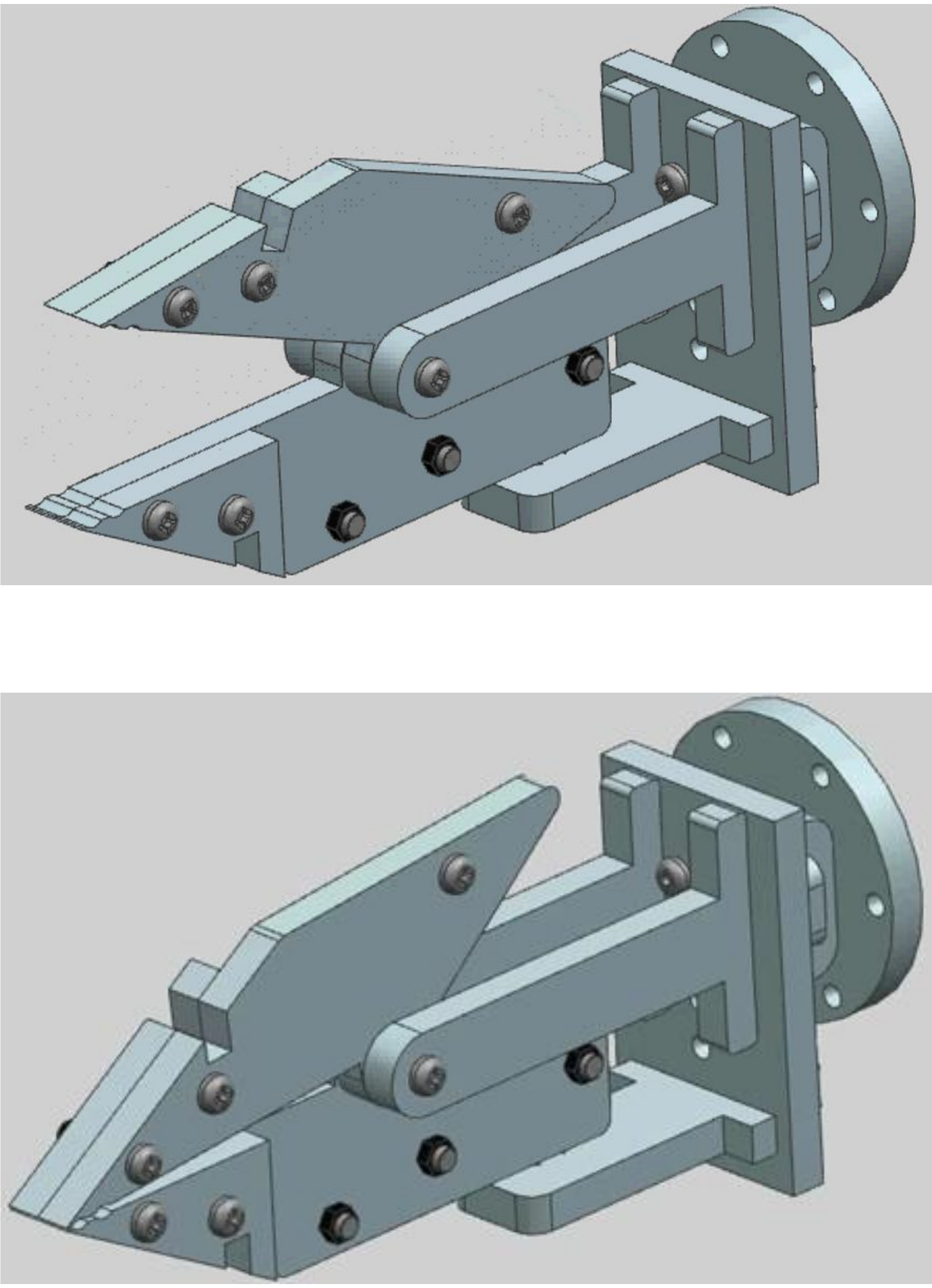


Figure 2.4 Open and shut mode.

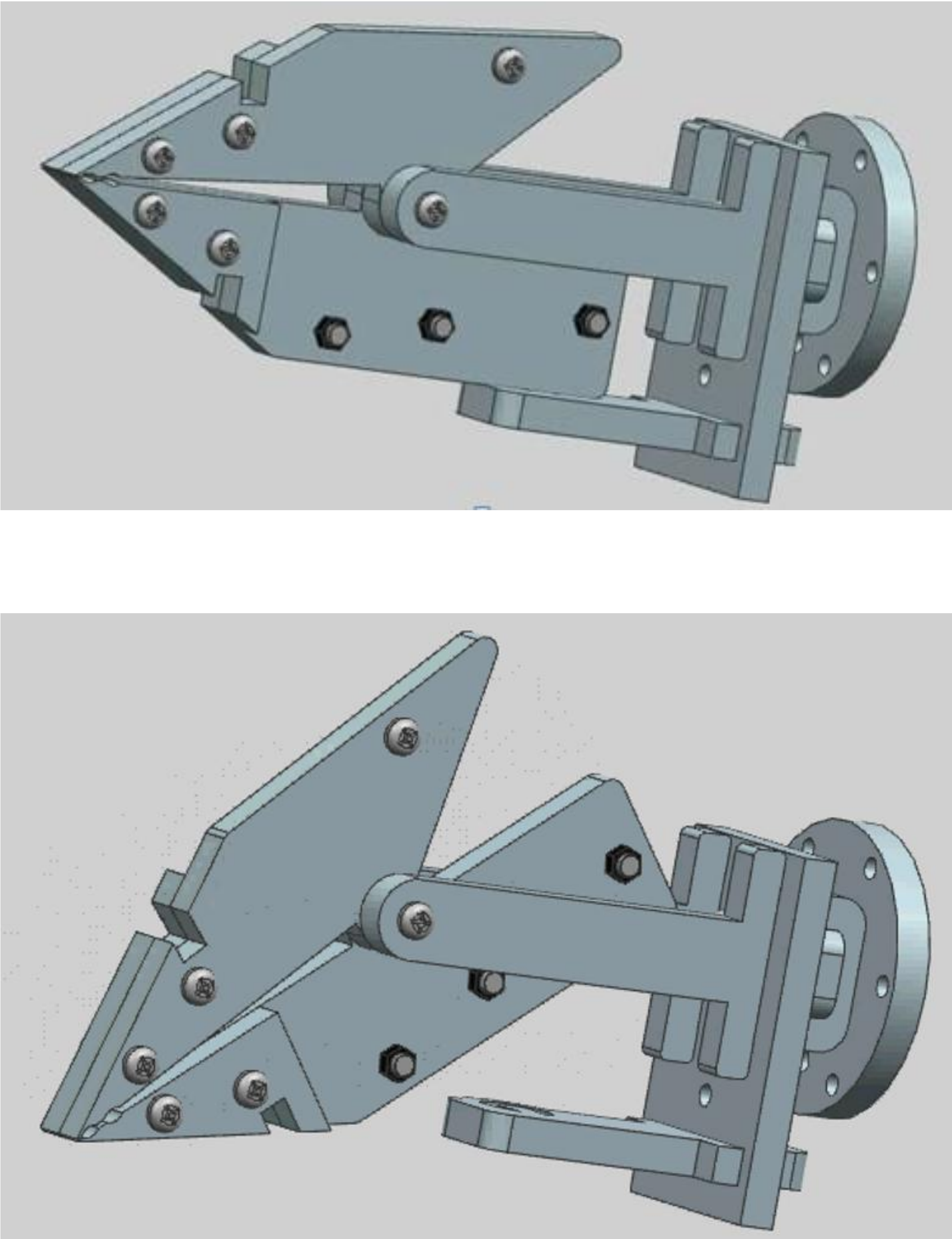


Figure 2.5 Tilt mode.

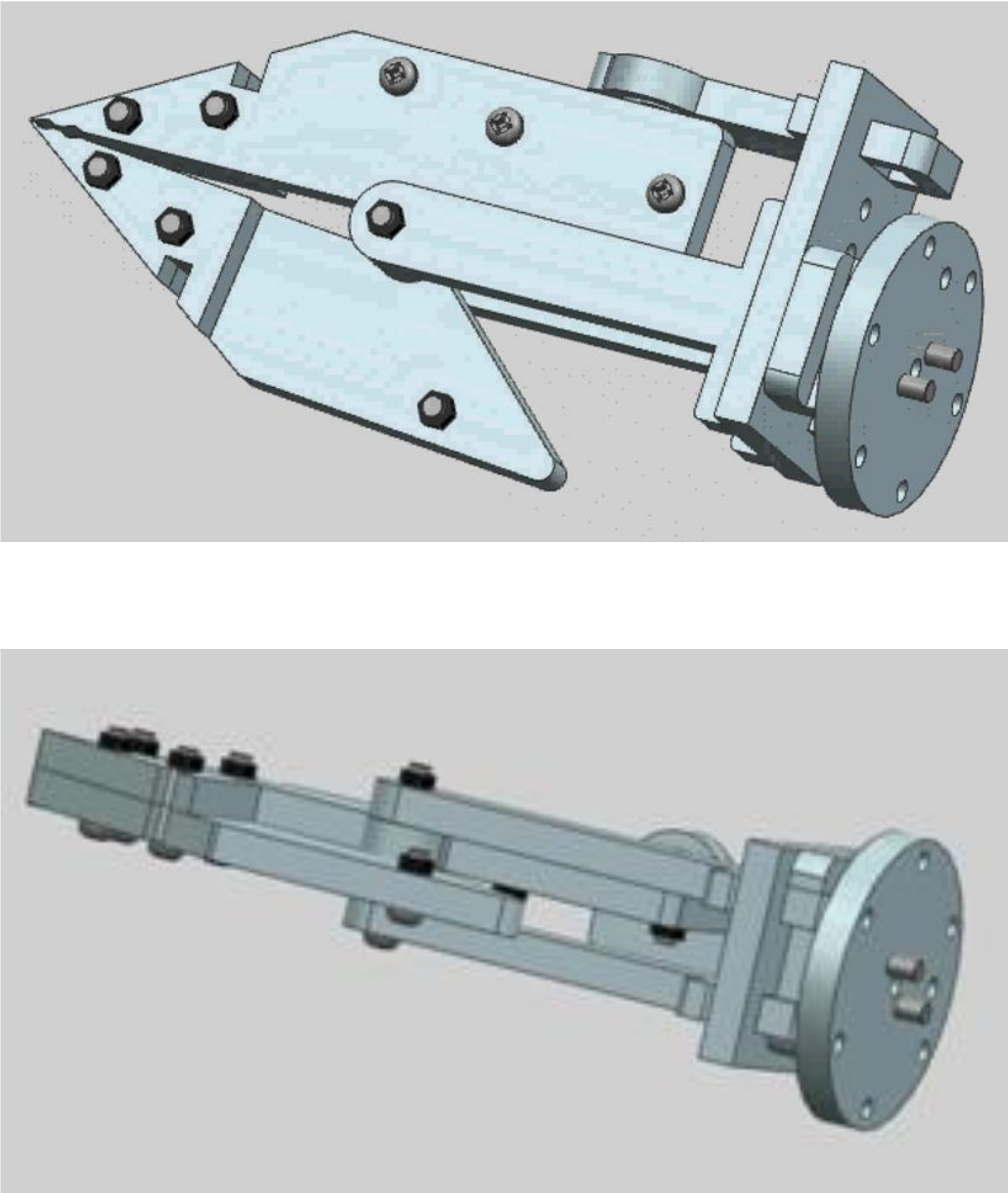


Figure 2.6 Rotation mode.

3. MANUFACTURING

This section provides all details related to the manufacturing process of the mechanical hands. It is comprised of two main parts, Materials and Tools and Manufacturing Process.

3.1 Materials and Tools

3.1.1 Materials

- **Acrylic glass**

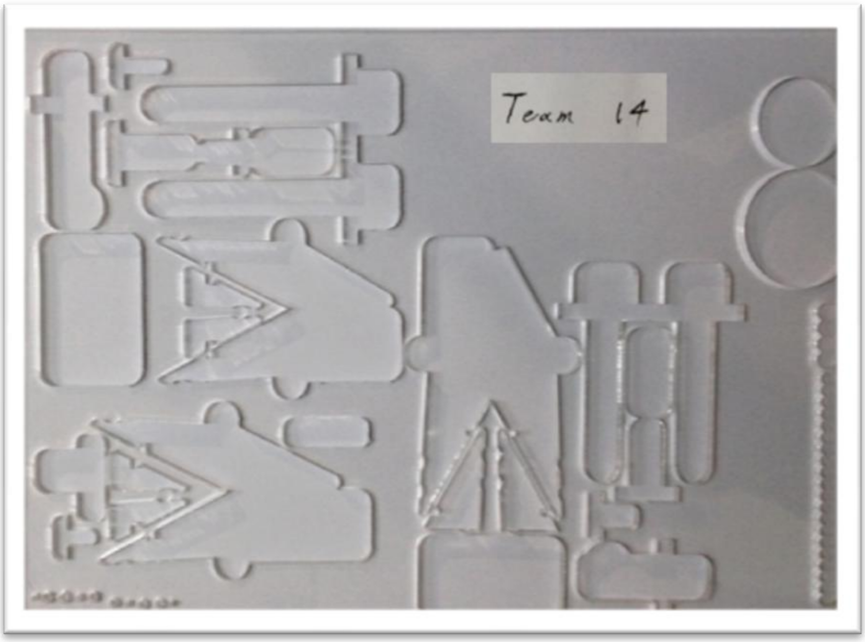


Figure 3.1 Acrylic glass.

Acrylic glass is mainly comprised of Poly (methyl methacrylate). Poly (methyl methacrylate) (PMMA) is a transparent thermoplastic often used as a lightweight or shatter-resistant alternative to glass. We use it to build our mechanical hands because PMMA is light, easy for further processing, as well as has satisfactory stiffness. Thus, we choose Acrylic glass to build our mechanical hands.

- **PVC pipes**

Figure 3.2 PVC pipes.

PVC pipes are mainly made from Poly (vinyl chloride), the third-most widely produced polymer, after polyethylene and polypropylene. PVC has high hardness as well as good mechanical properties. Not only has it low density, but also it possesses large elastic modulus. Besides, the cost of PVC is relatively low. These are the reasons why we choose PVC pipes to build our mechanical arms.

- **PVC joints**

Figure 3.3 PVC joints.

PVC joints are also made from Poly (vinyl chloride). They are used to connect the separated PVC pipes. PVC joints have many types, such as linear joint, T-shape joint, and angled T-shape joint.

- **Gears**

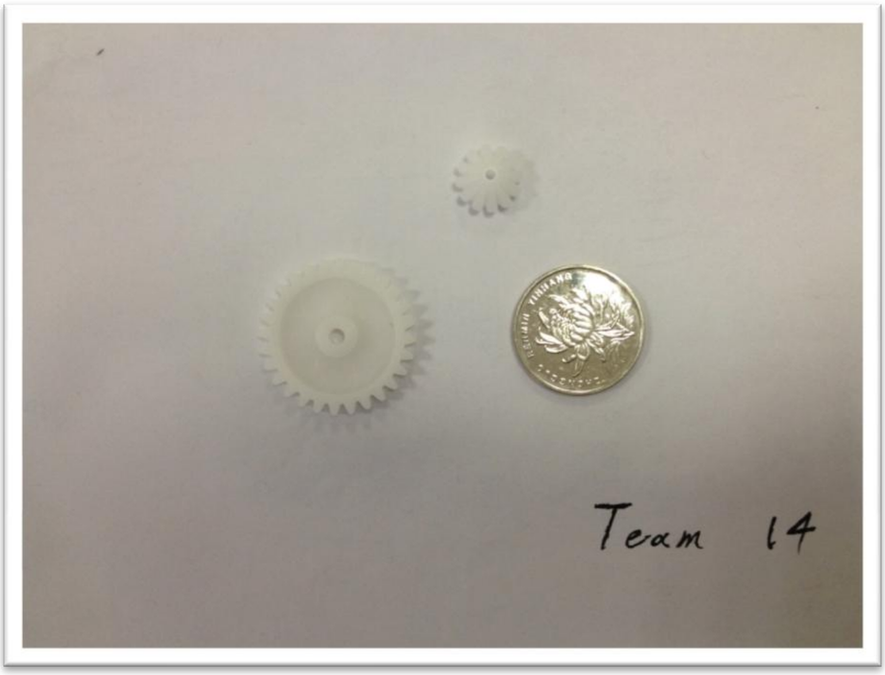


Figure 3.4 Gears.

A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear. There are many types of gears, such as spur, bevel and worm. In this project, we use gears to realize the rotation mode of the mechanical hands.

- **Shafts**

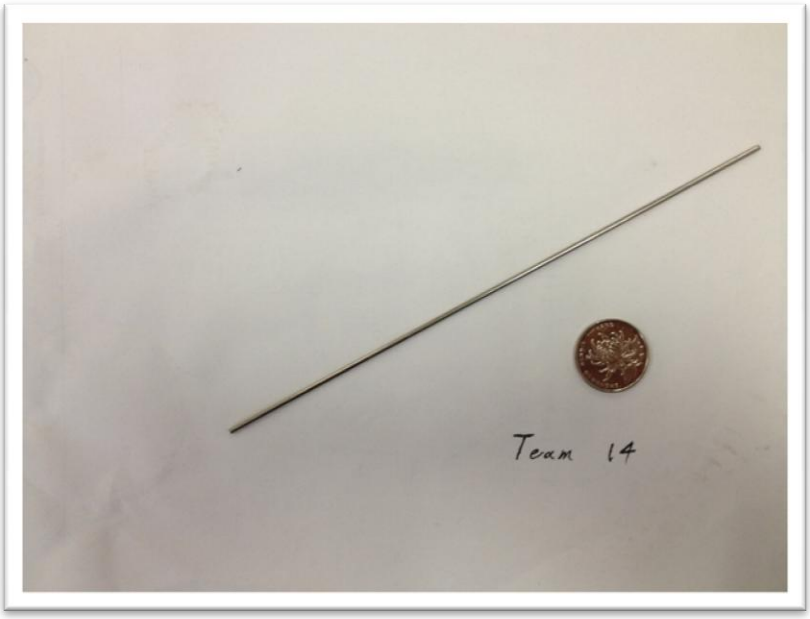


Figure 3.5 Shafts.

Shafts are used for a rotating wheel or gear. We use shafts to fix the rotating axis of the gears.

- **Kite string**

Figure 3.6 Kite string.

Kite string is much stronger than ordinary cotton thread. We use it to transmit tension so that the mechanical hands can open and tilt.

- **Elastics**

Figure 3.7 Elastics.

The mechanical hand is initially shut due to the existence of elastics. When we jerk the string, the elastic will be stretched so that the mechanical hand can open. When we jerk the other one, the other elastic will be stretched so that the mechanical hand can tilt.

- **Bolts and nuts**

Figure 3.8 Bolts and nuts.

Bolts and nuts are used to combine all the components of the mechanical hand.

3.1.2 Tools

- Laser cutting machine
- Drilling machine
- Hammer
- Screwdriver
- Saw
- Scissors
- Brush

3.2 Manufacturing Process

3.2.1 Preliminary Working

- **CAD works of the mechanical hand**

Before laser cutting, a CAD works is required, shown in Figure 3.9.

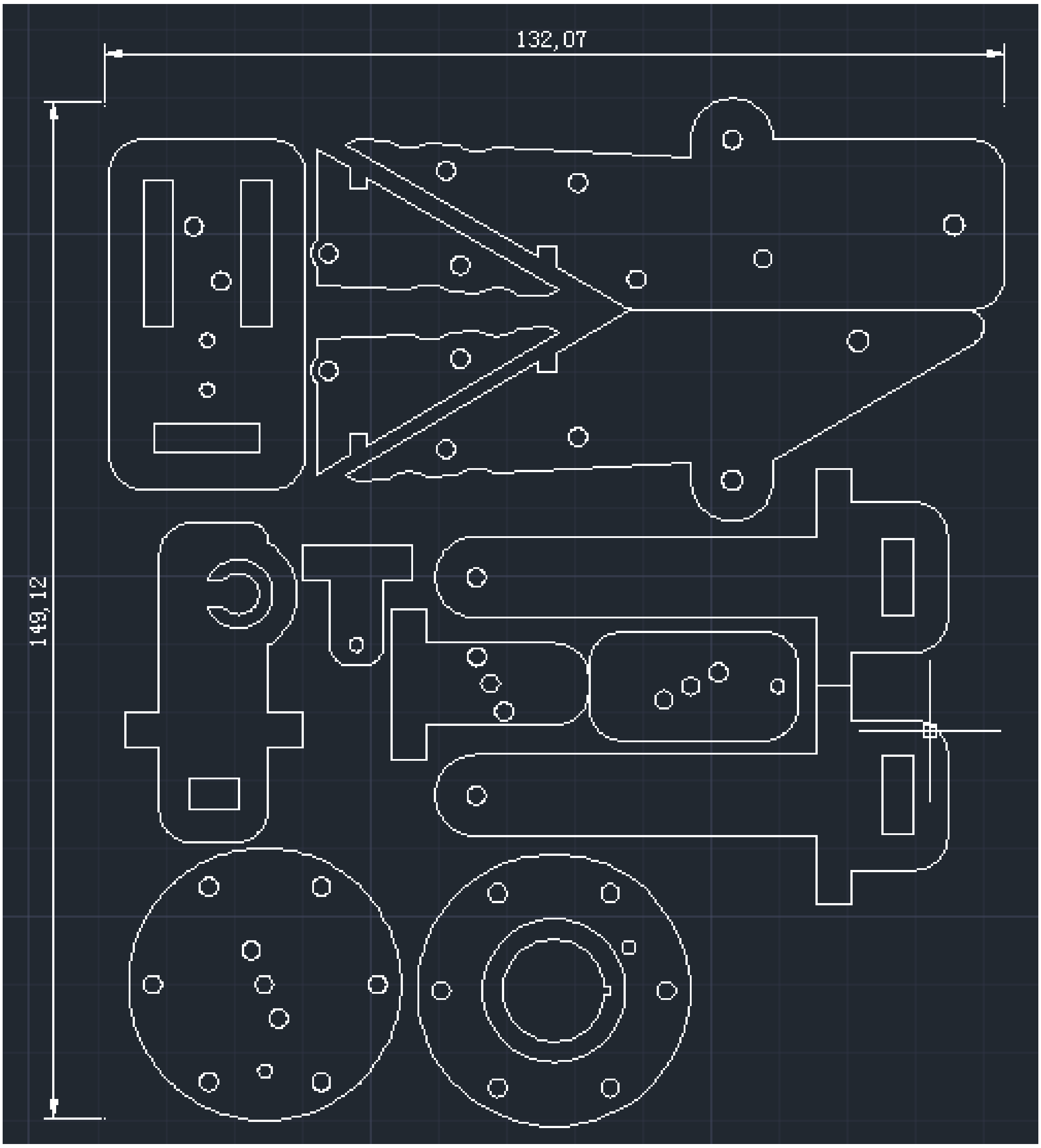


Figure 3.9 CAD works of the mechanical hand

(All dimensions in mm).

- **Detailed dimension of the mechanical arm**

Figure 3.10 shows all the dimensions of the mechanical arm. To build our mechanical arm, we need one 2000 mm PVC pipes, six T-shape PVC joints, two angled PVC joints and 4 PVC caps.

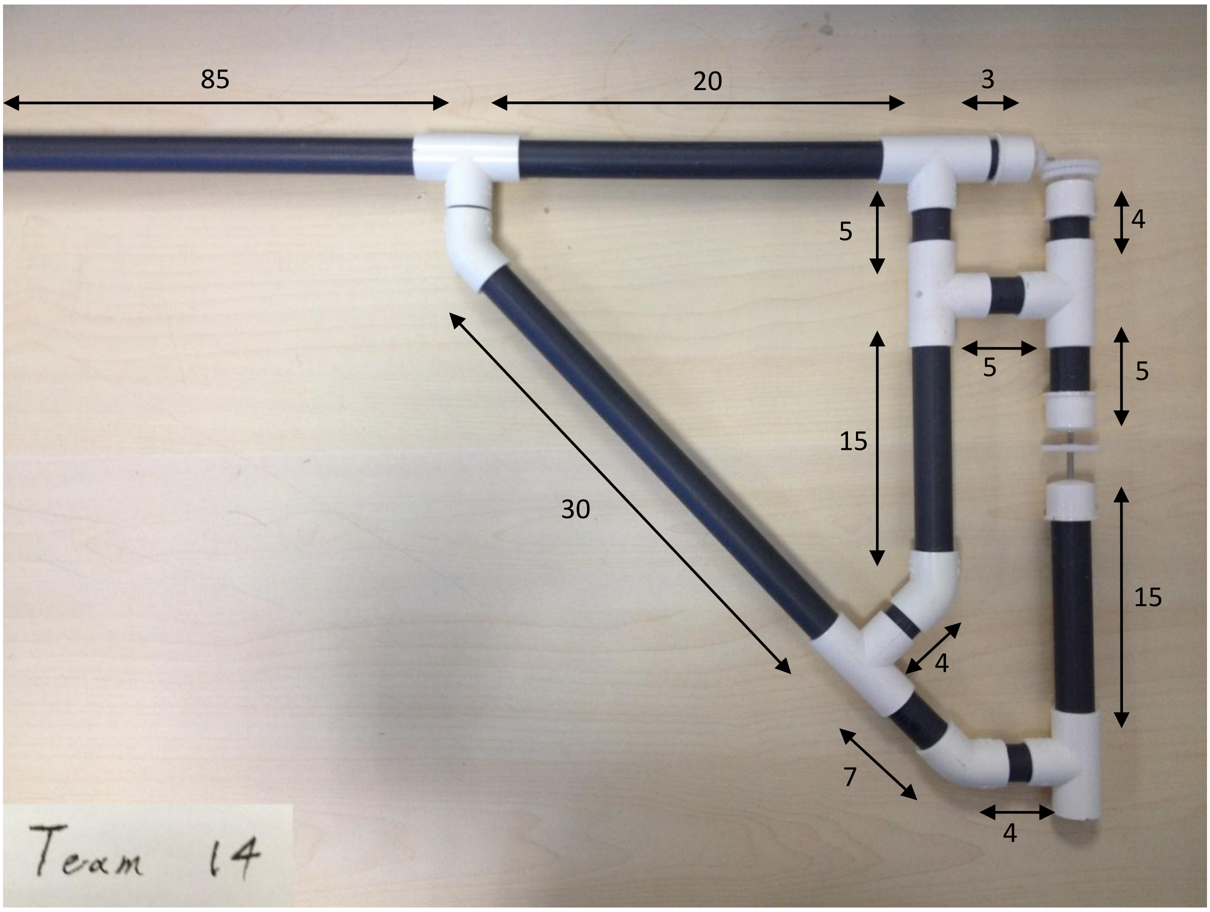


Figure 3.10 Dimensions of the mechanical arm.

(All dimensions in cm).

- **Connection of shafts**

Since the length of the shafts we bought from TaoBao is only 200 mm, it is far from enough. Thus, we need to connect several shafts together. Figure 3.11 shows the CAD works of the shaft joint. Figure 3.12 shows the realization of the connection of the shafts.

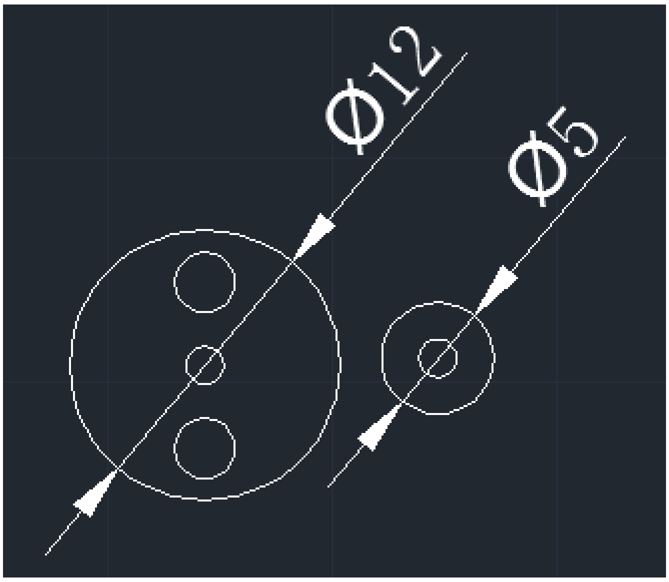


Figure 3.11 CAD works of the shaft joint.

Figure 3.12 Connection of shafts.

3.2.2 Assembly

- **Mechanical hand**

Laser cutting machine is used to cut all the components of the mechanical hands from the Acrylic board.

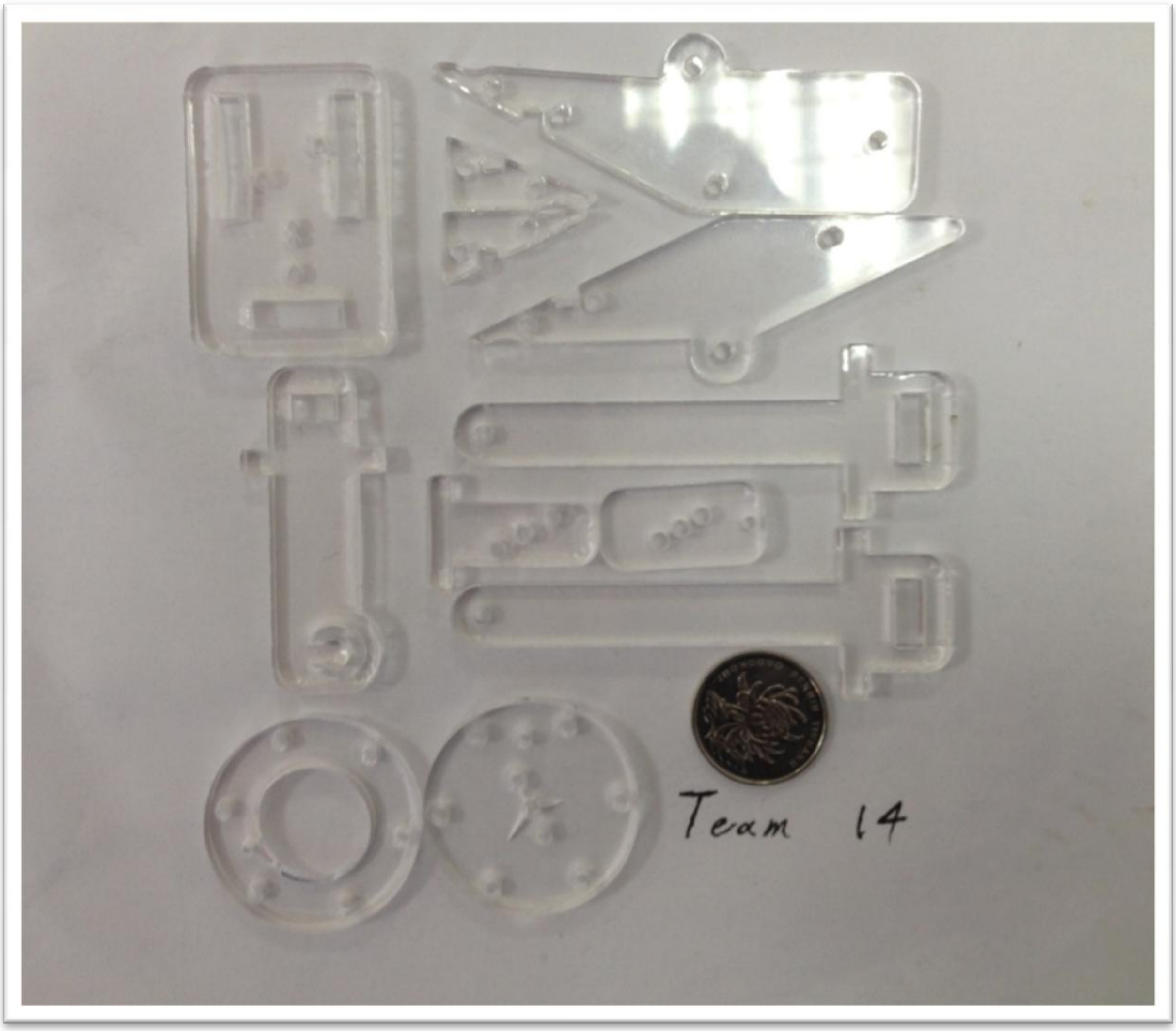


Figure 3.13 Components of the mechanical hand.

After cutting, we use bolts and nuts to combine them together with a screwdriver.

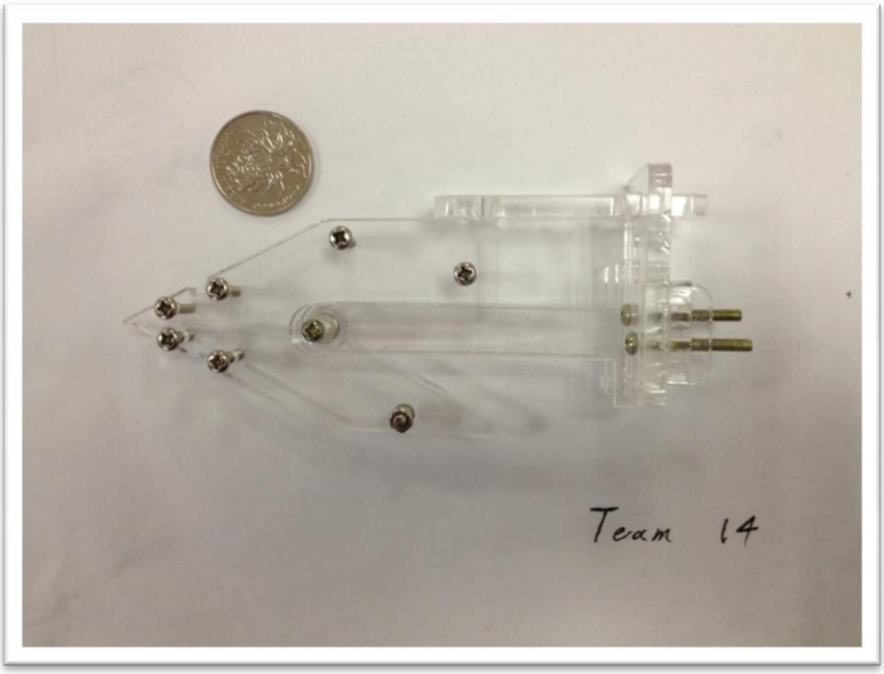


Figure 3.14 Combination of all components.

Finally, we fasten strings and elastics on the mechanical hand.

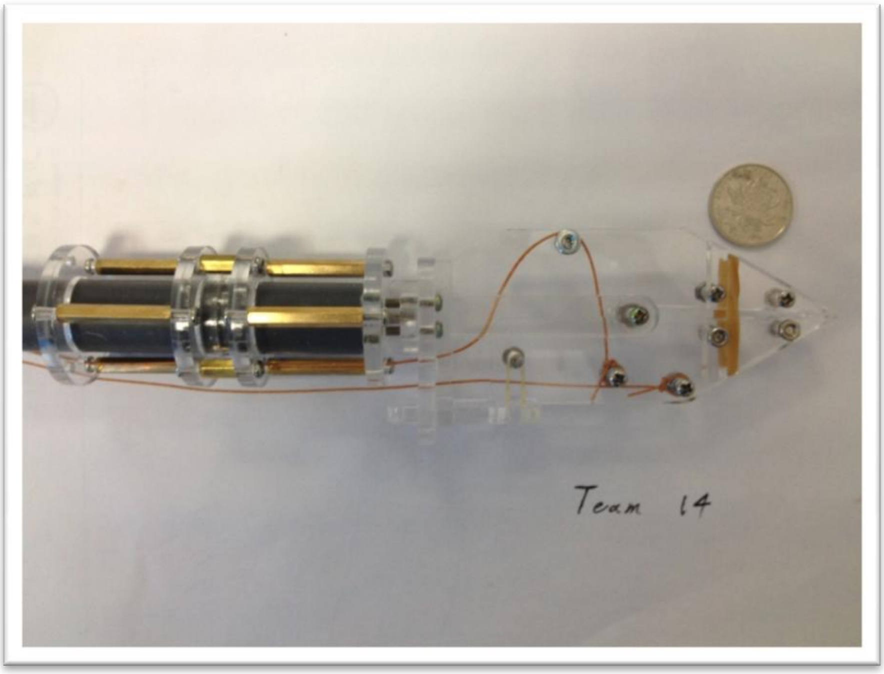


Figure 3.15 Assembled mechanical hand.

- **Mechanical arm**

With all the preceding dimensions, we use saw to cut all the components of the mechanical arm from PVC pipes.

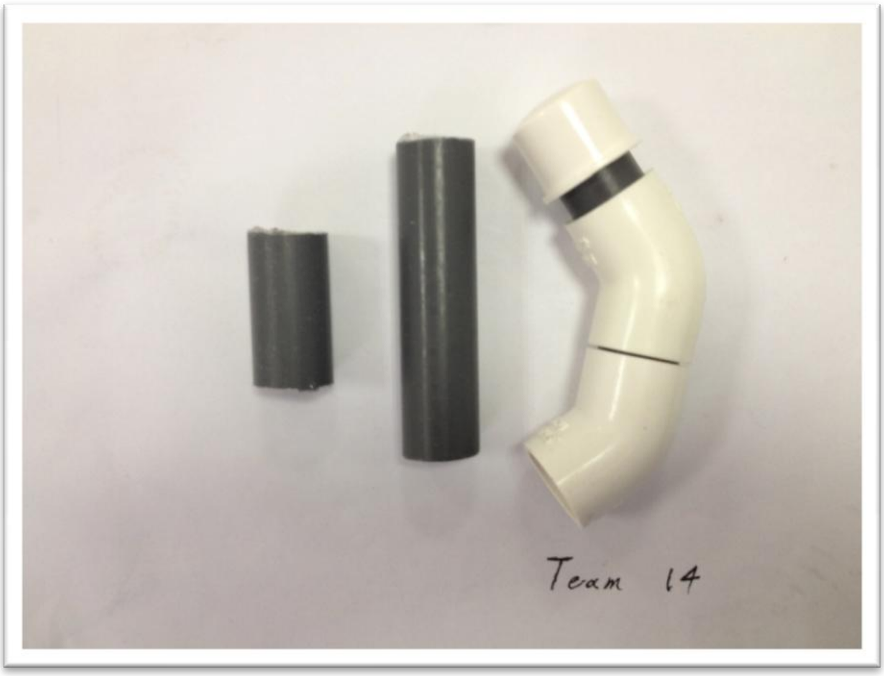


Figure 3.16 Components of the mechanical arm.

Assemble all the components according to the design.

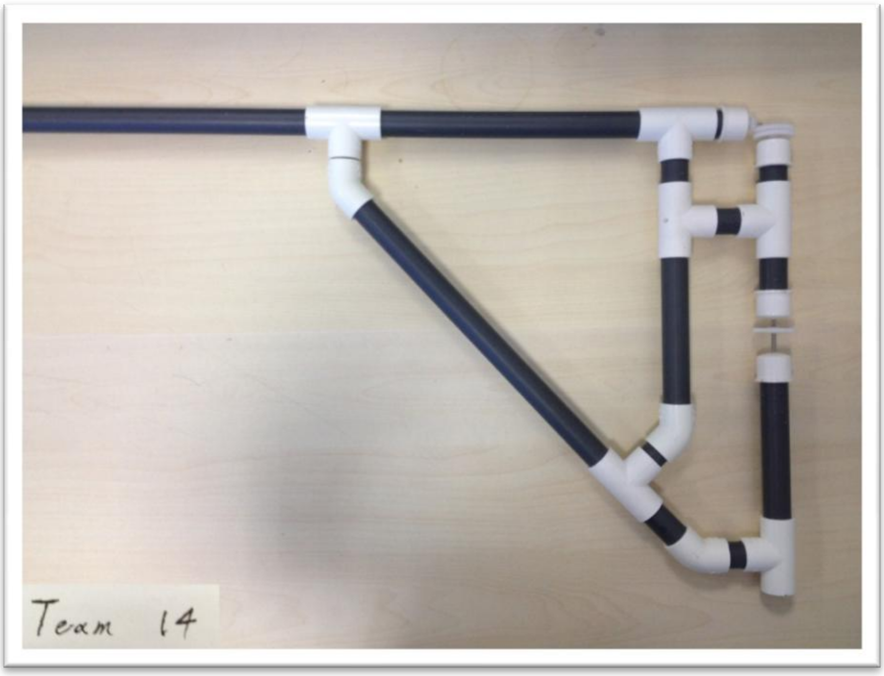


Figure 3.17 Assembled mechanical arm.

- **Final Prototype**

Finally, assemble all the preceding parts (mechanical hand, mechanical arm and connected shafts) together and the final prototype is shown below.

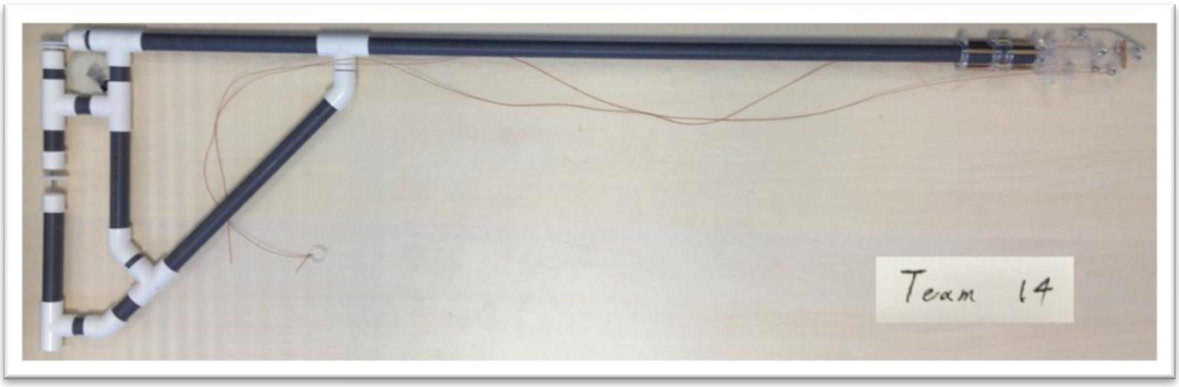


Figure 3.18 Final prototype.

4. IMPERFECTION

This section provides the imperfections we found after testing our mechanical hands. There are four main imperfections, Deformation, Heavy Weight, Inflexible Gearing and Fragile Joint.

4.1 Deformation

Firstly of all, the deformation is too large. As shown in the Figure 4.1, we can find that the bar bends too much.

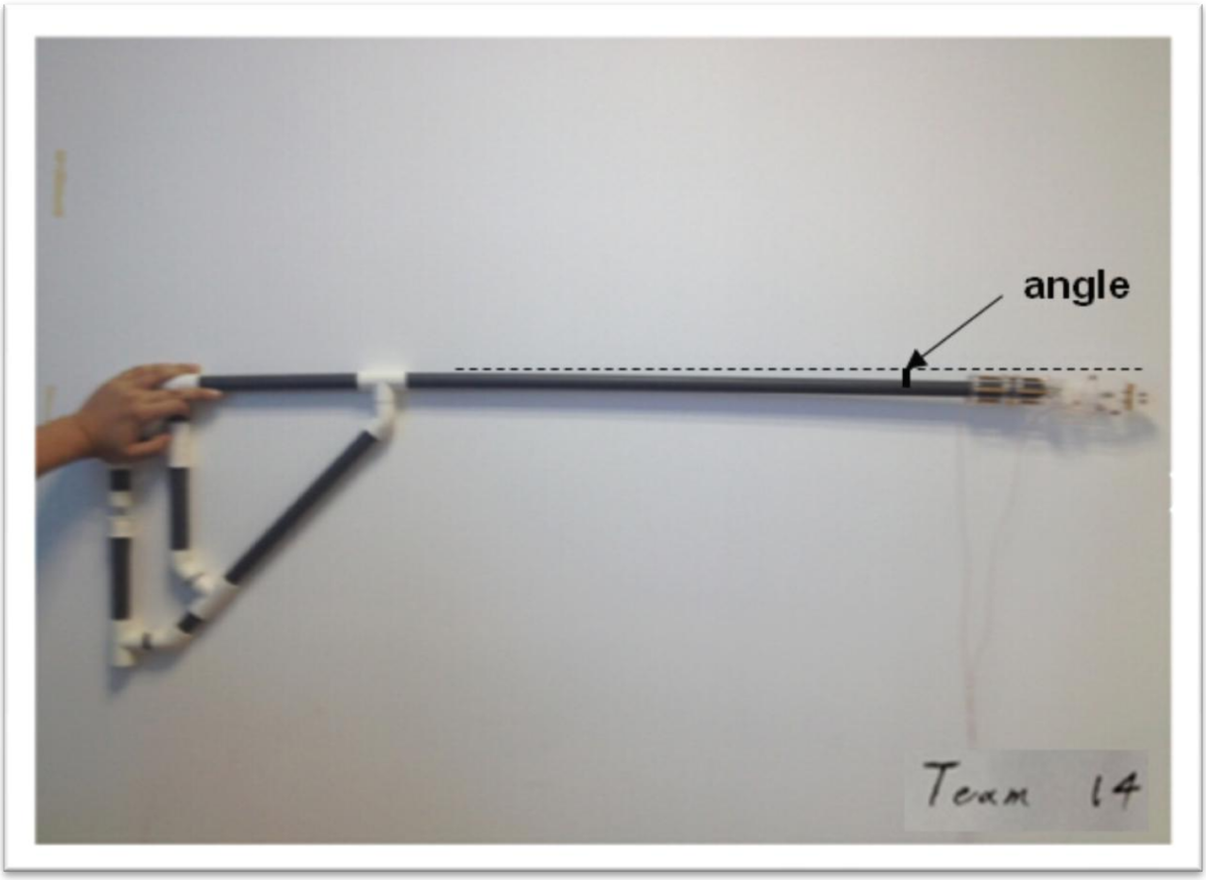


Figure 4.1 Deformation.

4.2 Heavy Weight

Secondly, each mechanical hand weights 416 g. Thus, it is so heavy that one can harldy hold the mechanical hand for a long time.

Figure 4.2 Heavy weight.

4.3 Inflexible Gearing

Thirdly, there are some problems in the gears meshing. Although large force is needed to make this part work, it still cannot work smoothly.

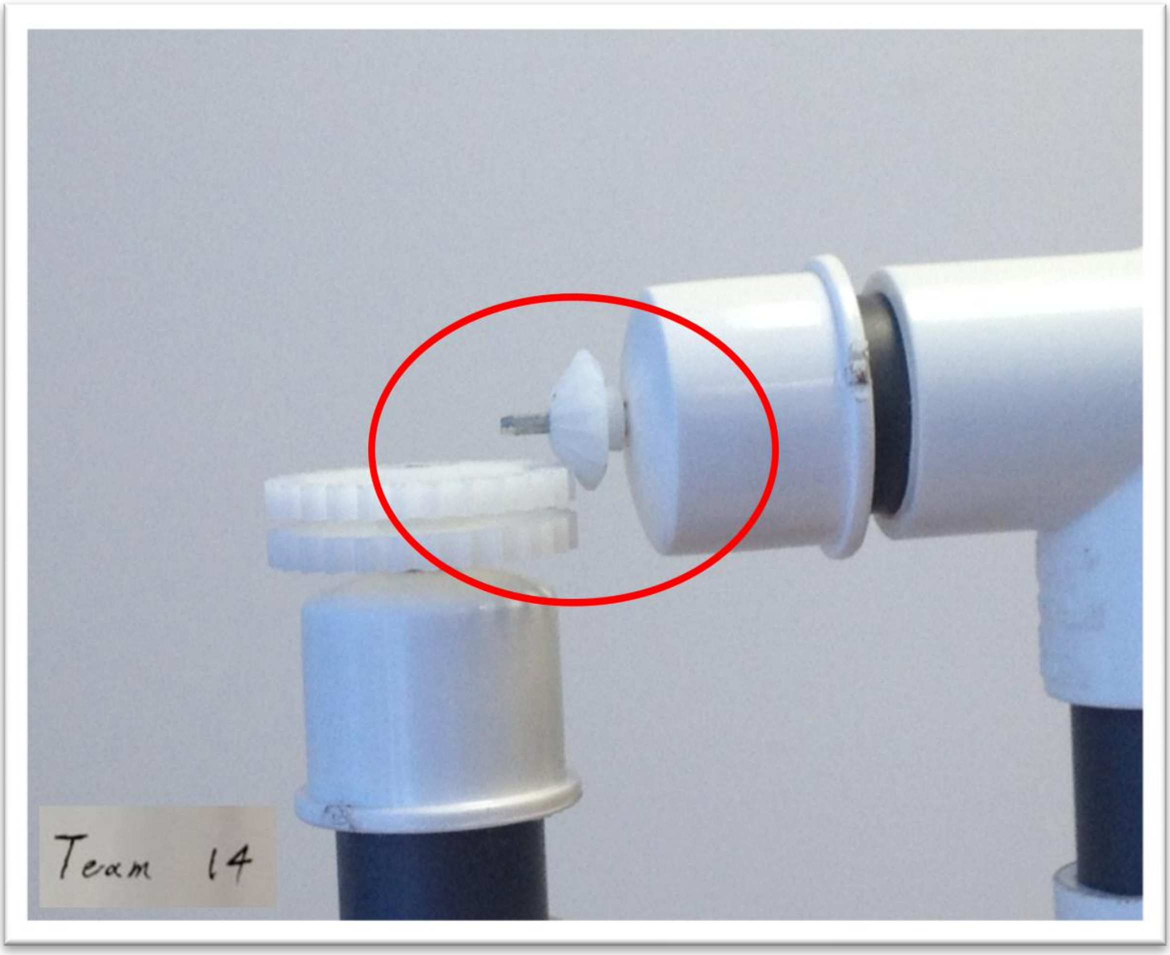


Figure 4.3 Inflexible gearing.

4.4 Fragile Joints

Meanwhile, the joint is not tight and it affects the life span seriously.

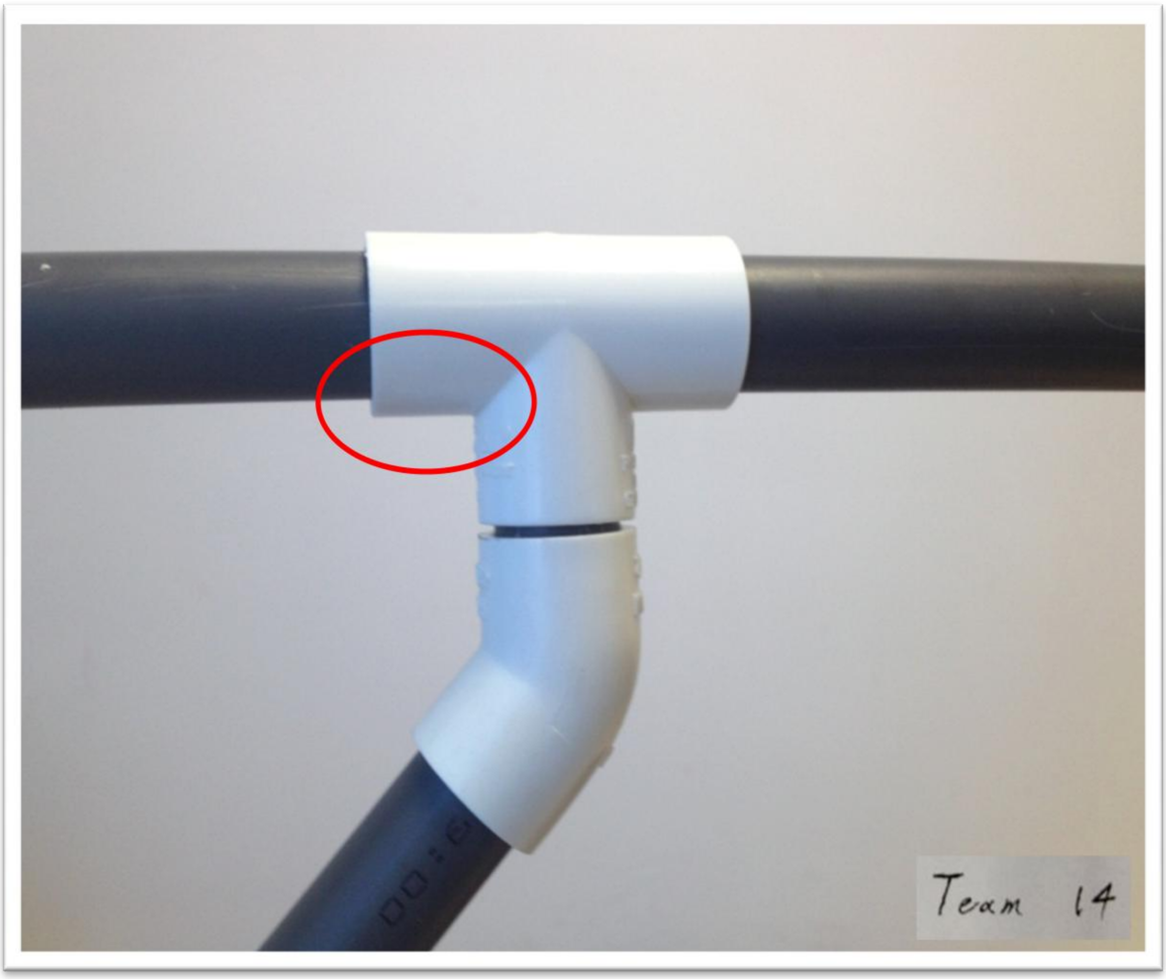


Figure 4.4 Fragile joint.

5. RECOMMENDATION

This section provides some recommendations we come up with in order to solve the preceding imperfections. It is comprised of four main parts, Add Holder, Change Material, Adjust the Location of Gears and Glue the Joint.

5.1 Add Holder

Firstly, add holder and belt to the end of the bar so that the deformation and the force applied by hands will be reduced according to the mechanical theory.

5.2 Change Material

Secondly, substitute some other material with larger Young's modulus and smaller density for PVC pipes. Consequently, the deformation would be much less obvious and the weight would be much lighter.

5.3 Adjust the Location of Gears

Thirdly, adjust the location of gears so that they may work much more smoothly.

5.4 Glue the Joints

Finally, use glue to stick the joints so that they may become much firmer.

6. COST ANALYSIS

This section provides details about the cost analysis of the mechanical hands. It is comprised of two main parts, Cost for Prototype and Cost for Mass Production.

6.1 Cost for Prototype

6.1.1 Material Cost

Here is the cost table of all the materials we used in our final prototype. The material we used is economical and durable. However, they may not be the best material to select.

Material	**Cost**
PVC pipes	￥60
Gears and shafts	￥5
Kite string	￥1
Elastics	￥1
Bolts and nuts	￥5
Acrylic board	￥20
Total cost	**￥92**

Table 6.1 Material cost of the final prototype.

Thus, material cost is ￥92.

6.1.2 Overhead Cost

Also, we need to consider the cost for labor.

Assume each teammate should be paid ￥30 per hour and the total working time is 36 hours for each.

Thus, overhead cost is determined to be ￥5400.

6.1.3 Total Cost

The total cost of our final prototype is ￥5492.

6.2 Cost for Mass Production

6.2.1 Material Cost

The cost of material will be lower if we buy a large number of them.

Material	**Cost**
PVC pipes	￥50
Gears and shafts	￥4
Kite string	￥0.8
Elastics	￥0.8
Bolts and nuts	￥5
Acrylic board	￥15
Total cost	**￥75.6**

Table 6.2 Material cost of the mechanical hands.

6.2.2 Tooling Cost

For this part and next part, since we cannot manufacture in the factory by ourselves, we just gather some information on the Internet to estimate the cost.

- **Laser cutting machine**

Assume each machine requires one new tool set which costs ￥10,000, and the production rate per machine is 30 pairs/hr.

Each machine produces one product at a time.

The factory operates 7 hours per day, 5 days a week and 50 weeks per year.

$$C_{cutting} = \frac{C_t}{n}\{Int(\frac{n}{n_t} + 0.51)\} = 0.52$$

Thus, the tooling cost of cutting board is ￥0.52/pair.

- **Drilling machine**

Assume each machine requires one new tool set which costs ￥1,000, and the production rate per machine is 40 pairs/hr.

The factory operates 7 hours per day, 5 days a week and 50 weeks per year.

$$C_{drilling} = \frac{C_t}{n}\{Int(\frac{n}{n_t} + 0.51)\} = 0.12$$

Thus, the tooling cost of drilling the pipe is ￥0.12/pair.

6.2.3 Equipment Cost

- **Laser cutting machine**

Assume each machine costs ￥20,000, and the production rate per machine is 30 pairs/hr. The life time is 20,000 hours.

Each machine produces one product at a time.

$$C_{\text{cutting}} = \frac{1}{\dot{n}}(\frac{C_c}{Lt_{wo}}) = 0.53$$

Thus, the equipment cost of cutting board is ￥0.53/pair.

- **Drilling machine**

Assume each machine costs ￥15,000, and the production rate per machine is 40 pairs/hr. The life time is 25,000 hours.

Each machine produces one wristband at a time.

$$C_{drilling} = \frac{1}{\dot{n}}(\frac{C_c}{Lt_{wo}}) = 0.25$$

Thus, the equipment cost of drilling the board is ￥0.25/pair.

6.2.4 Overhead Cost

The cost of overhead includes the cost of labor, energy and facilities. And the estimation is based on the data from the Internet.

Assume each worker is paid ￥30 per hour and the cost of energy and facilities is ￥40 per hour.

$$C_4 = \frac{C_{oh}}{\dot{n}} = 2.4$$

Thus, the overhead cost is ￥2.4/pair.

6.2.5 Total Cost

Therefore, the total cost is $C_1 + C_2 + C_3 + C_4$ =￥79.37/pair. The price of our product is relatively low, it is economical and practical.

7. CONCLUSION

For the mechanical hands, we mainly discuss about the material of each part and ways to control the mechanical hands. We simulate the process of tying knots by hand, and finally we decided to design a prototype with three freedoms, which can benefit the tying of knots at the greatest extent. In the end we use Acrylic (PMMA) board to build hands, PVC pipes to build arms, and use gears and thread to transmit tension and rotating angle.

We find that the design process is really difficult, but also interesting. Before this project, we only know some specific terms or concept such as CR, ES, and QFD from the book. Now, we realize that before design, we must apply all these knowledge to find out what our product really needs and how we can satisfy them.

Also, during the design, we must pay attention to every detail of the product. Our group once had to delay the whole assembly process due to one component with wrong dimension of a hole. It is really embarrassing. So, before drawing the CAD, we should have a clear idea of the product; think twice before confirming the dimension of each component. Detail makes perfect, after all.

Besides, the project teaches us to start early, since when we enjoy the project, there is always something unexpected, something you never thought of. If we don't have enough time to fix the problem, the results will be disappointing.

All in all, the project teaches us how to work as a team and cooperate with different people. The most important thing is that if we make joint efforts for the same goal, it will produce great energy.

I believe after the course, we will grow into more creative and professional future engineers.

8. REFERENCE

The preceding parts are all our own works, so there's no reference.

9. NOMENCLATURE

9.1 PMMA

Poly (methyl methacrylate) (PMMA) is a transparent thermoplastic often used as a lightweight or shatter-resistant alternative to glass.

PMMA is routinely produced by emulsion polymerization, solution polymerization, and bulk polymerization. Generally, radical initiation is used (including living polymerization methods), but anionic polymerization of PMMA can also be performed. To produce 1 kg (2.2 lb) of PMMA, about 2 kg (4.4 lb) of petroleum is needed. PMMA produced by radical polymerization (all commercial PMMA) is atactic and completely amorphous.

PMMA is a strong and lightweight material. It has a density of 1.17–1.20 g/cm3, which is less than half that of glass. It also has good impact strength, higher than both glass and polystyrene; however, PMMA's impact strength is still significantly lower than polycarbonate and some engineered polymers. PMMA ignites at 460 ℃ (860 ℉) and burns, forming carbon dioxide, water, carbon monoxide and low-molecular-weight compounds, including formaldehyde.

Retrieved from http://en.wikipedia.org/wiki/Poly(methyl_methacrylate).

9.2 PVC

Poly (vinyl chloride), commonly abbreviated PVC, is the third-most widely produced polymer, after polyethylene and polypropylene.

PVC comes in two basic forms: rigid (sometimes abbreviated as RPVC) and flexible. The rigid form of PVC is used in construction for pipe, and in profile applications such as doors and windows. It is also used for bottles and other non-food packaging, and cards (such as bank or membership cards). It can be made softer and more flexible by the addition of plasticizers, the most widely used being phthalates. In this form, it is also used in plumbing, electrical cable insulation, imitation leather, signage, inflatable products and many applications where it replaces rubber. Pure poly (vinyl chloride) is a white, brittle solid. It is insoluble in alcohol, but slightly soluble in tetrahydrofuran.

PVC has high hardness and mechanical properties. The mechanical properties enhance with the molecular weight increasing, but decrease with the temperature increasing. The mechanical properties of rigid PVC (uPVC) are very good, the elastic modulus can reach to 1500-3,000 MPa. The soft PVC (Flexible PVC) elastic is 1.5-15 MPa. However, elongation at break is up to 200% -450%. PVC friction is ordinary, the static friction factor is 0.4-0.5, the dynamic friction factor is 0.23.

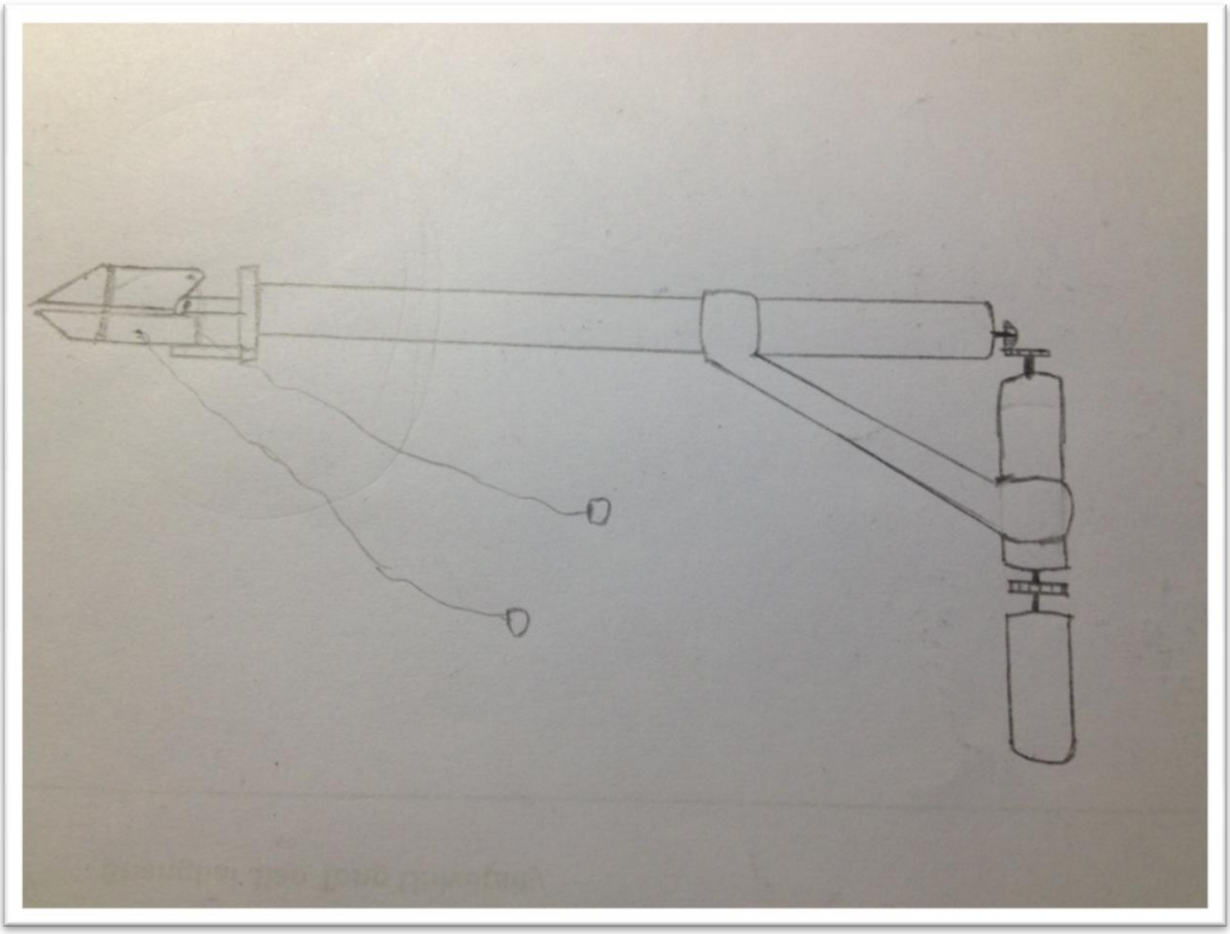
Retrieved from http://en.wikipedia.org/wiki/PVC.

10. ACKNOWLEDGEMENT

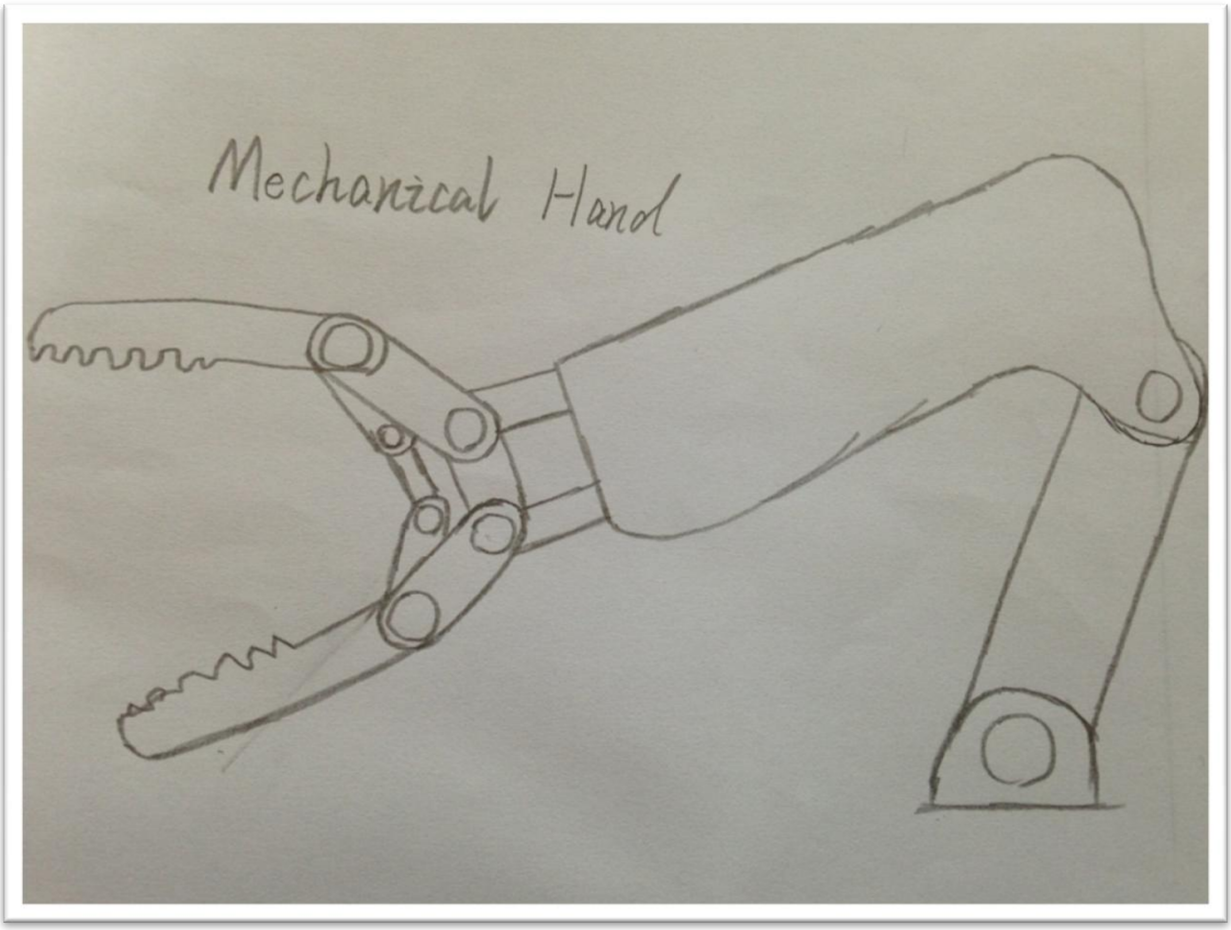
We want to appreciate anyone who has helped us in this project. In particular, we are grateful to Prof. Li Mian who gave us relative knowledge about design and manufacturing in his lecture. Without his lectures, it’s impossible for us to design such wonderful product. Besides, the three TAs, Xu Yang, Xiong Chuantang and Li Hao, all provided useful advices to us during the project.

APPENDIX I: ALL SKETCHES IN CONCEPT DESIGN

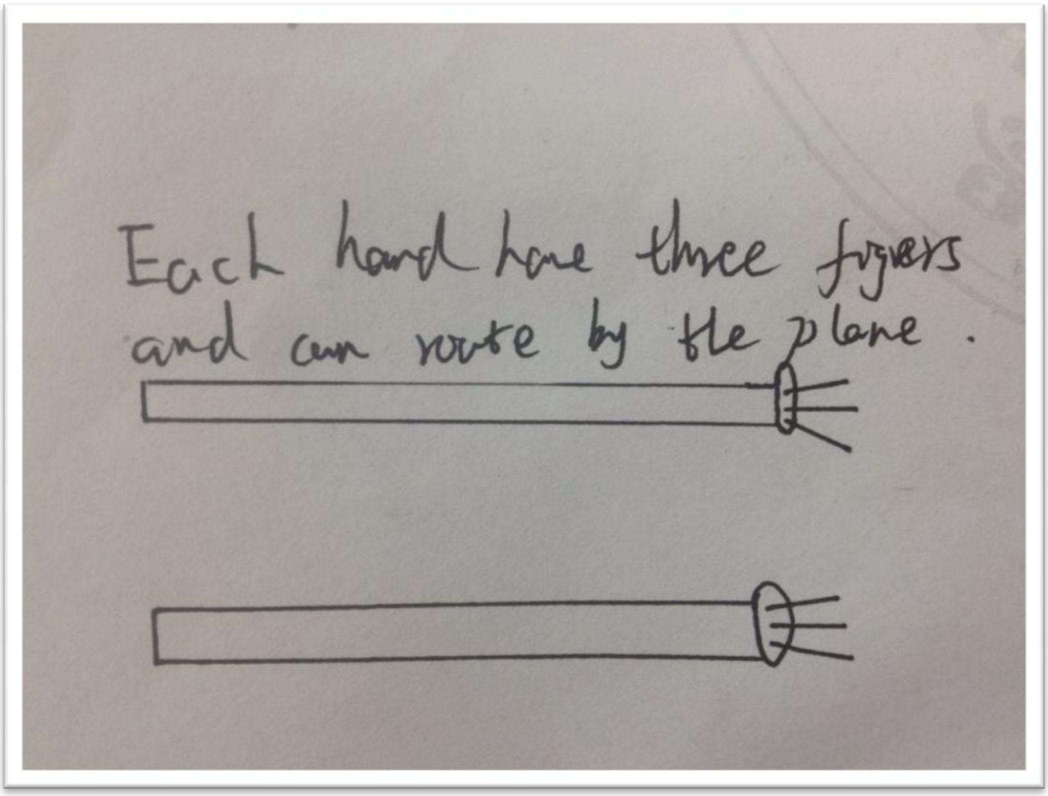
- **Sketch by teammate Chu Bei**



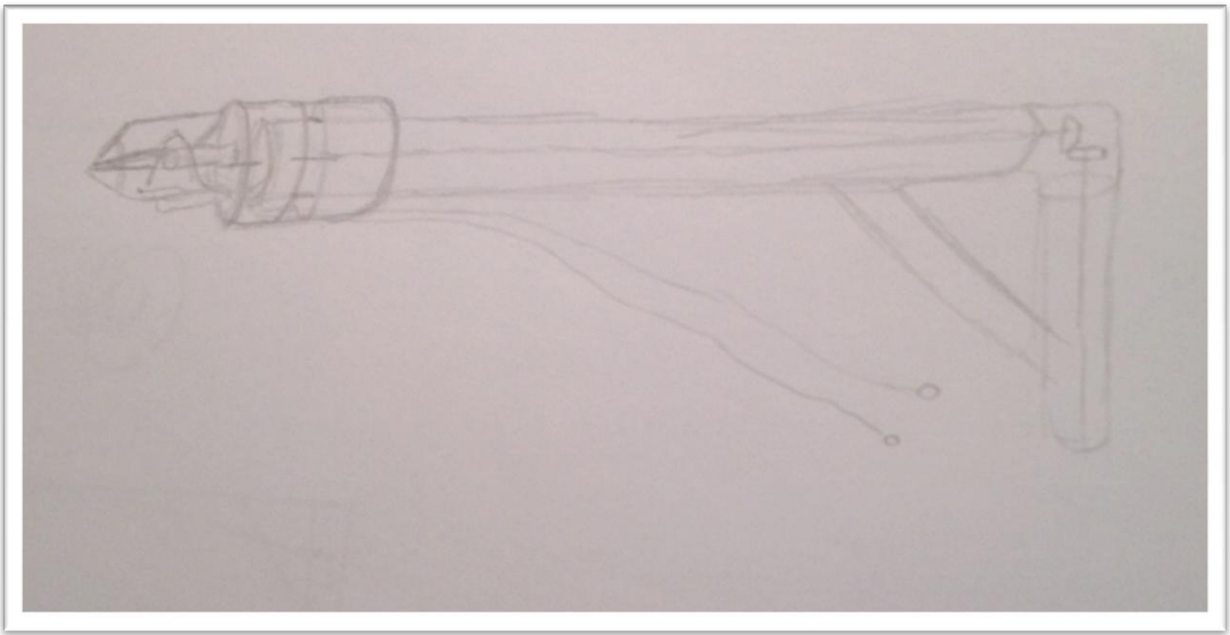
- **Sketch by teammate Huang Jianchi**



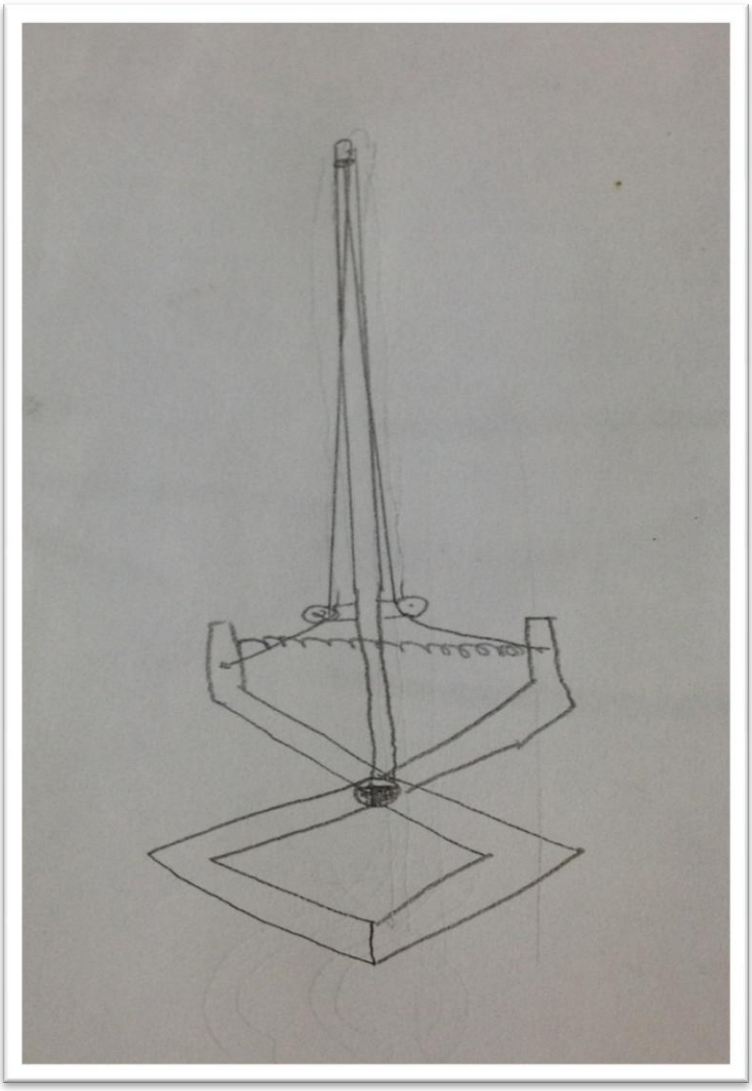
- **Sketch by teammate Liu HanYang**



- **Sketch by teammate Shen Junjie**

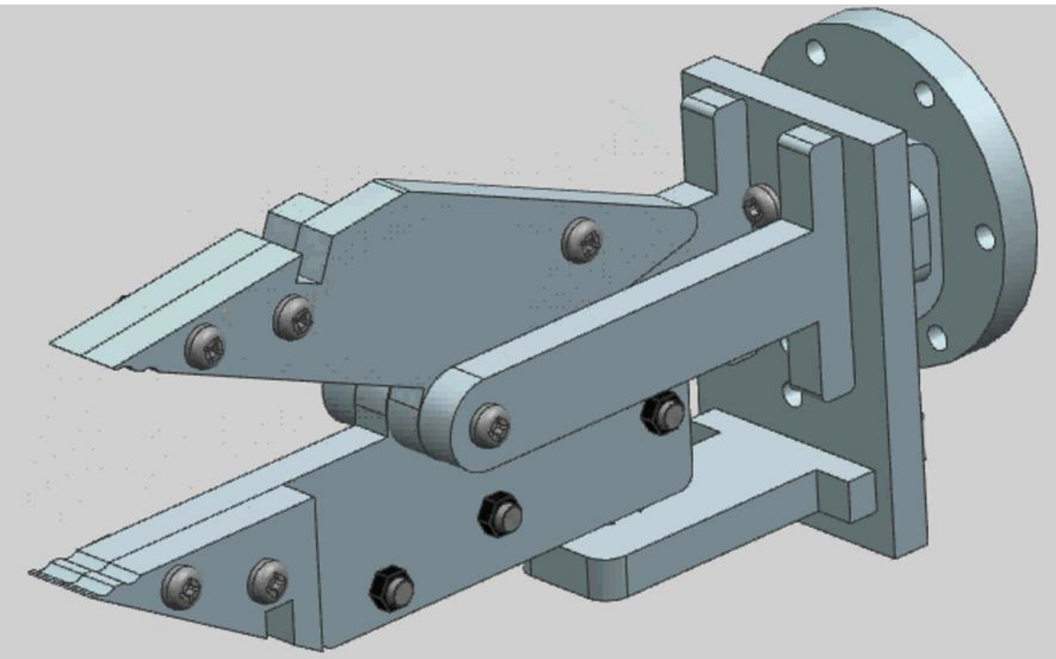


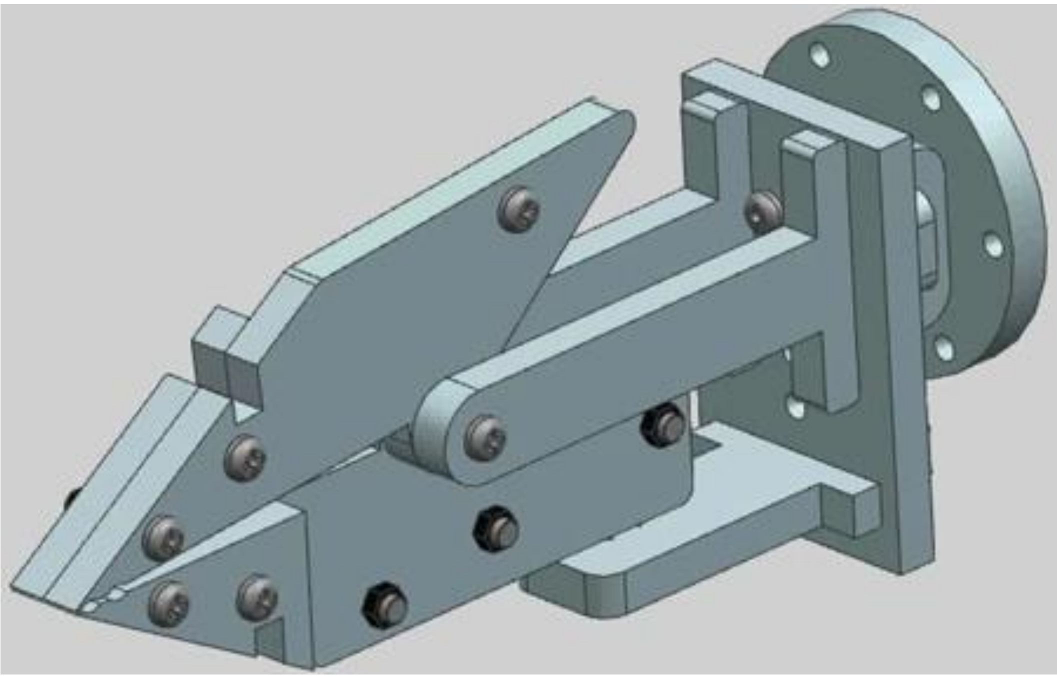
- **Sketch by teammate Shen Yang**



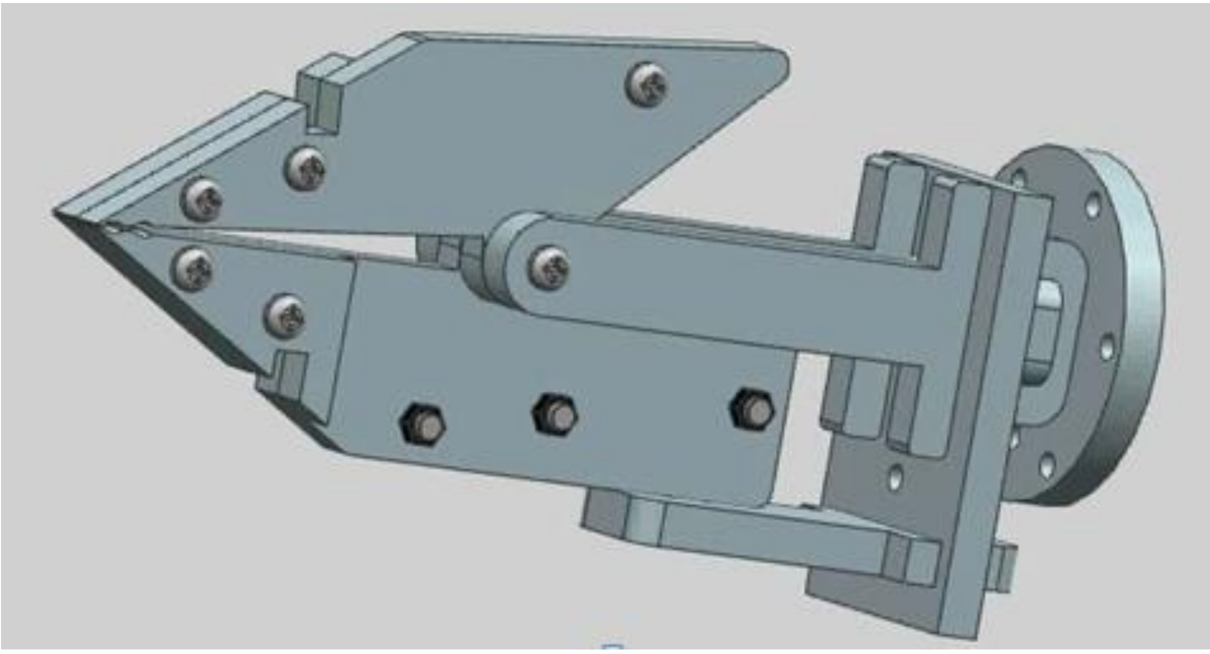
APPENDIX II: ALL ENGINEERING DRAWS WITH UG

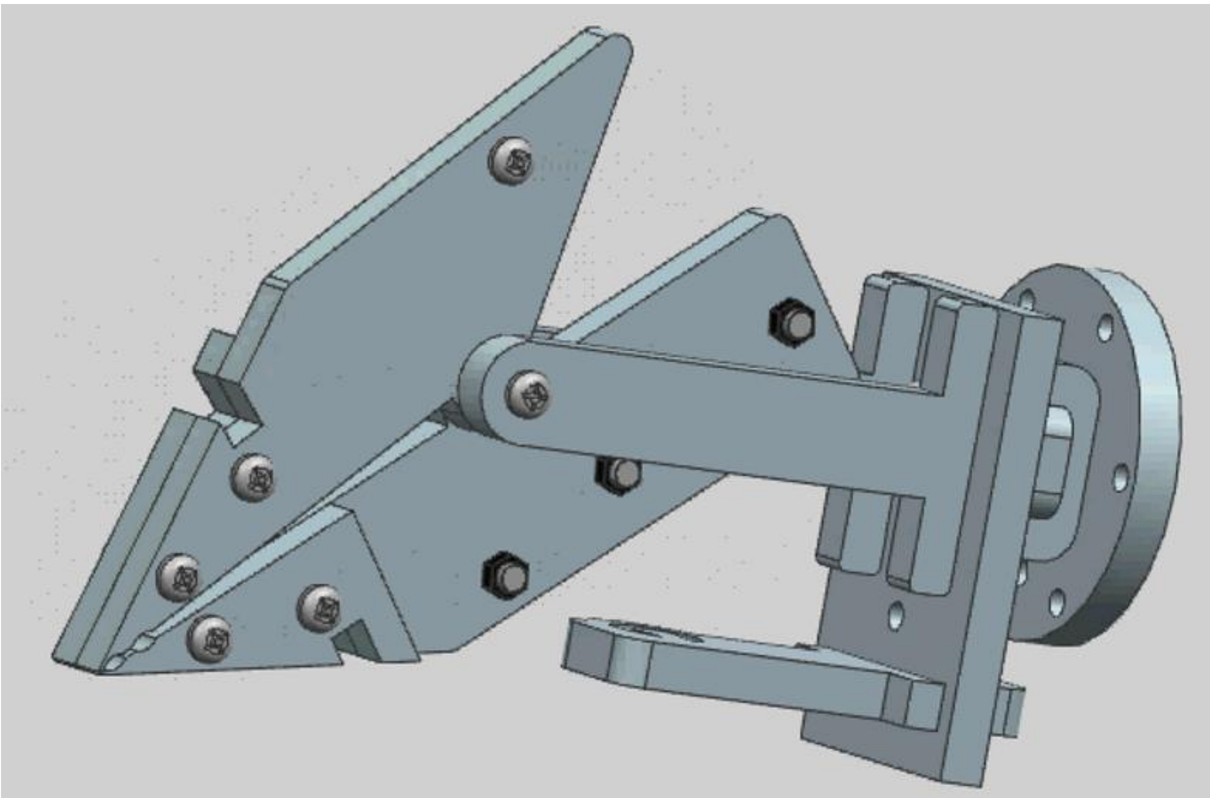
- **Open and shut**



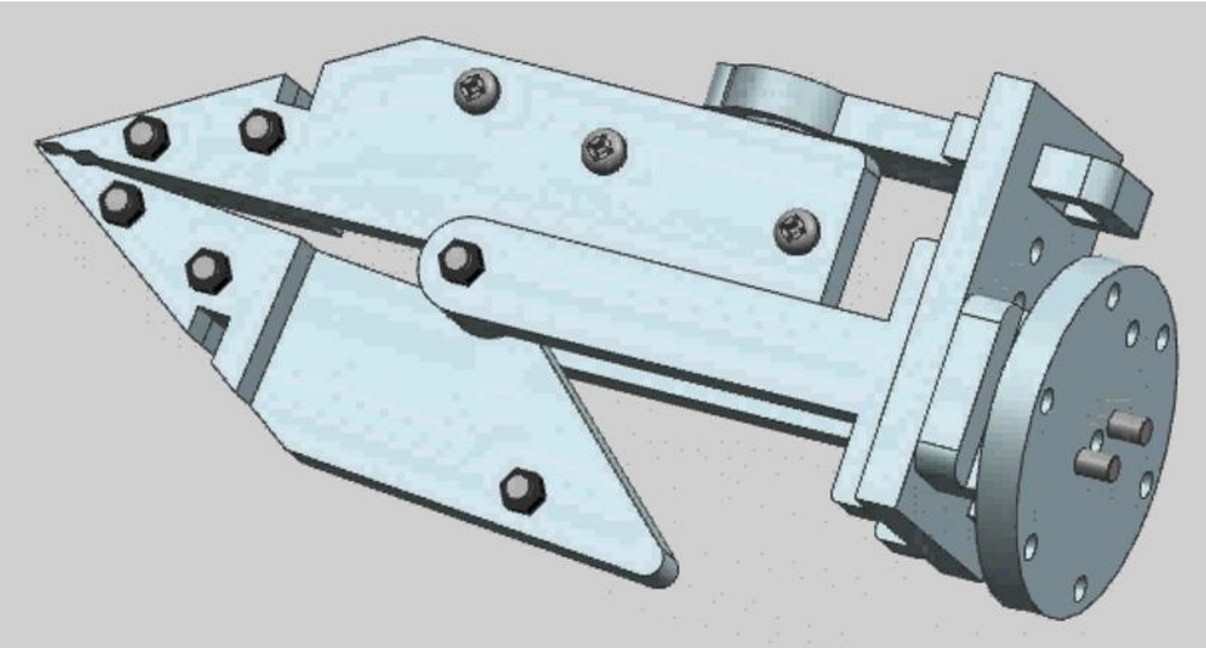


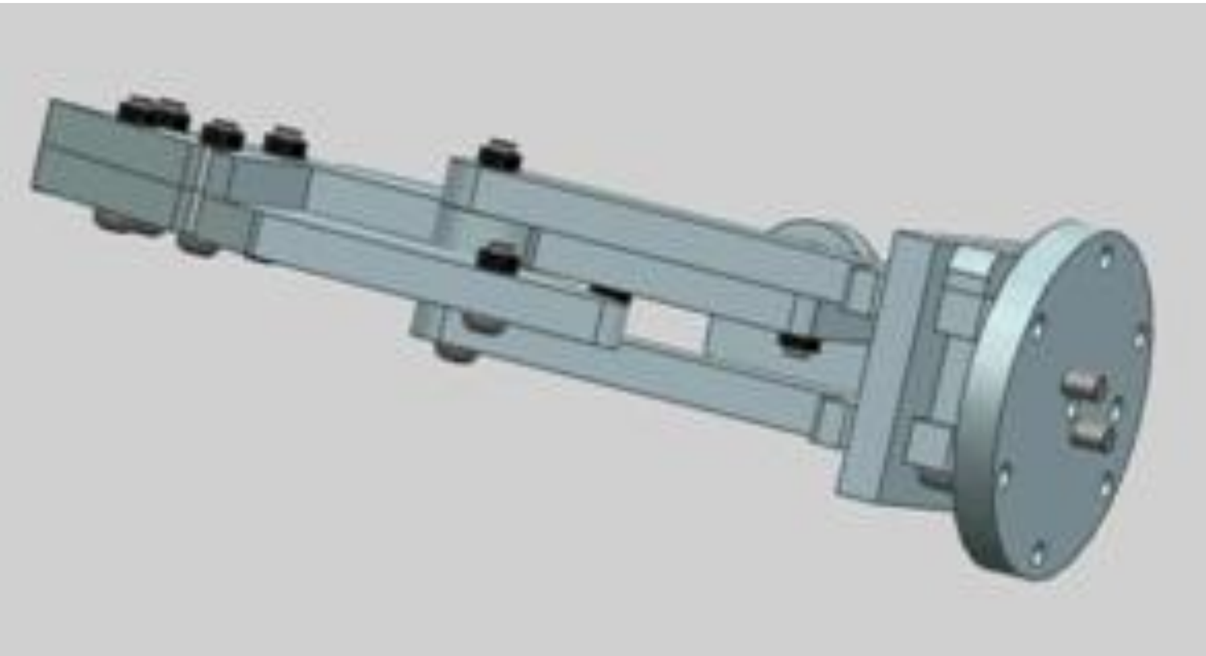
- **Tilt**





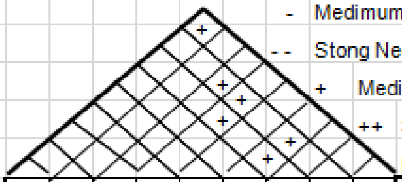
- **Rotation**





APPENDIX III: PRODUCT DESIGN SPECIFICATIONS

- **QFD**



- Medimum Negative
- - Stong Negative
+ Medimum Positive
++ Stong Positive

Benchmarks

	Weight (1-10)	rotating angle	friction coefficient	force	moment	effective spring constant	length	weight	max. defection	cost	*competitor A*	*competitor B*
looks good	3						9	3			5	2
light weight	6							9			4	4
handle comfortably	7				9			3			2	2
reasonable size	5						9				3	5
reasonable driving force	9	1	1	9	3	9					2	2
clamp the rope	10		9			9					3	4
inexpensive	4									9	1	3
last for a long time	8		3						9		3	4
Measurement Unit		.	/	lb	lb*ft	lb/ft	ft	lb	in	$		
Target Value												
Total		9	123	81	90	171	72	84	72	36		
Normalized		0.01	0.17	0.11	0.12	0.23	0.10	0.11	0.10	0.05		
competitor A												
competiotor B												

Competitive benchmarks

5 = satisfies perfectly
4 = satisfies "mostly"
3 = satisfies "somewhat"
2 = satisfies "slightly"
1 = doesn't satisfy at all

Correlation between customer reqs and eng. Specs

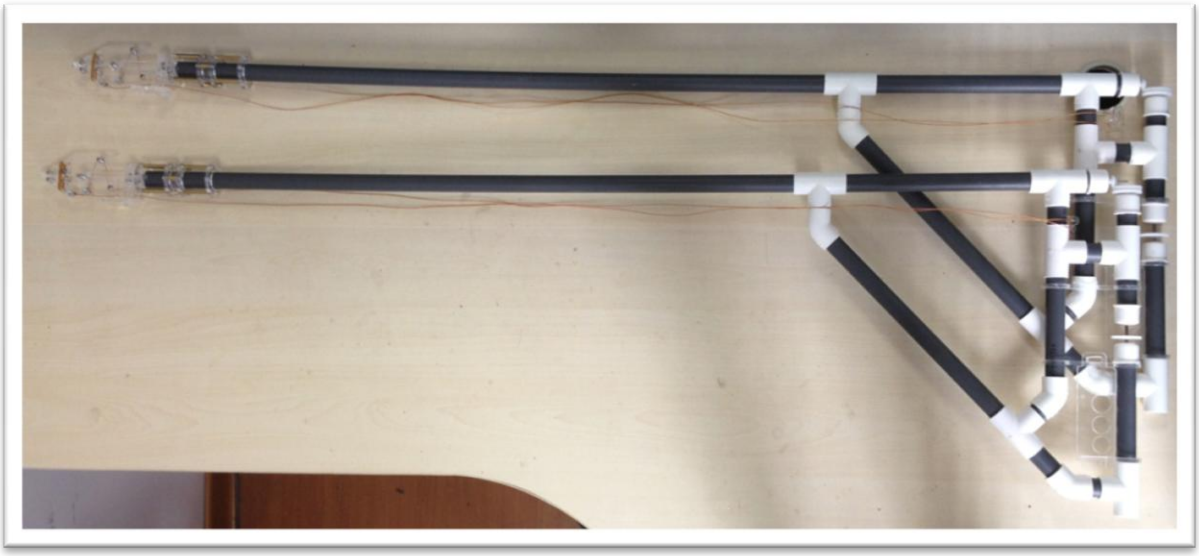
9 = Strong Relationship
3 = Medium Relationship
1 = Small Relationship
(blank) = Not Related

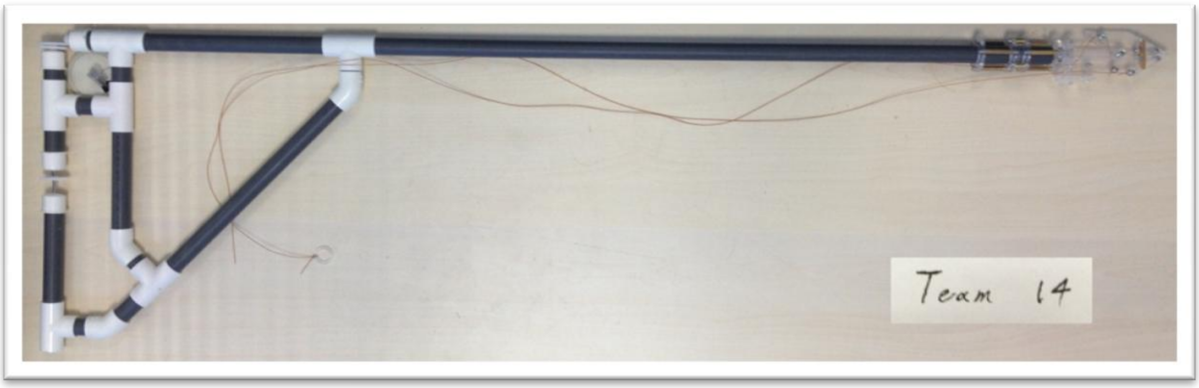
- **PDS**

Items	Detailed Specifications
Performance	• Should finish many types of knots at 1.2 m • Should be one-man operated • Should be handheld ones
Size	1.10 m (length) * 0.6 m (width)
Weight	0.416 kg each
Cost	￥92
Product Life Span	At least one year
Material	• Plastic • Rubber • Steel
Driving force	No more than 10 N
Safety	• Avoid sharp corner, all edges should be polished smooth • Surface should be polished smoothly

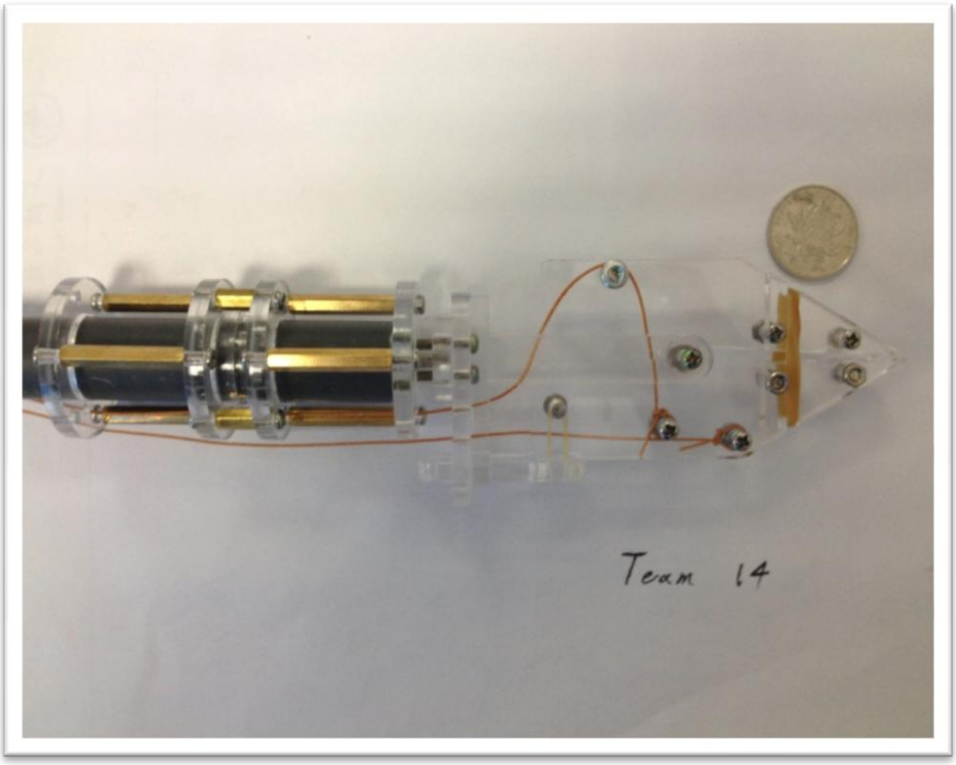
APPENDIX IV: DETAILS OF PROTOTYPED MACHINES

- **Final Prototype**

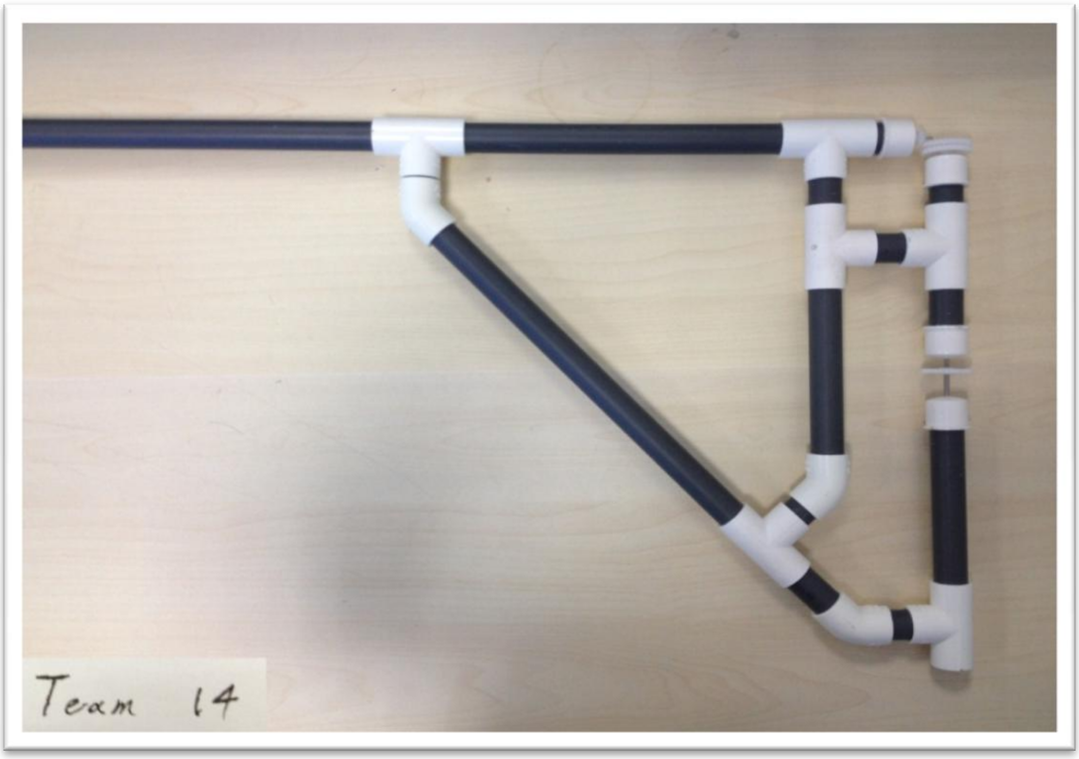




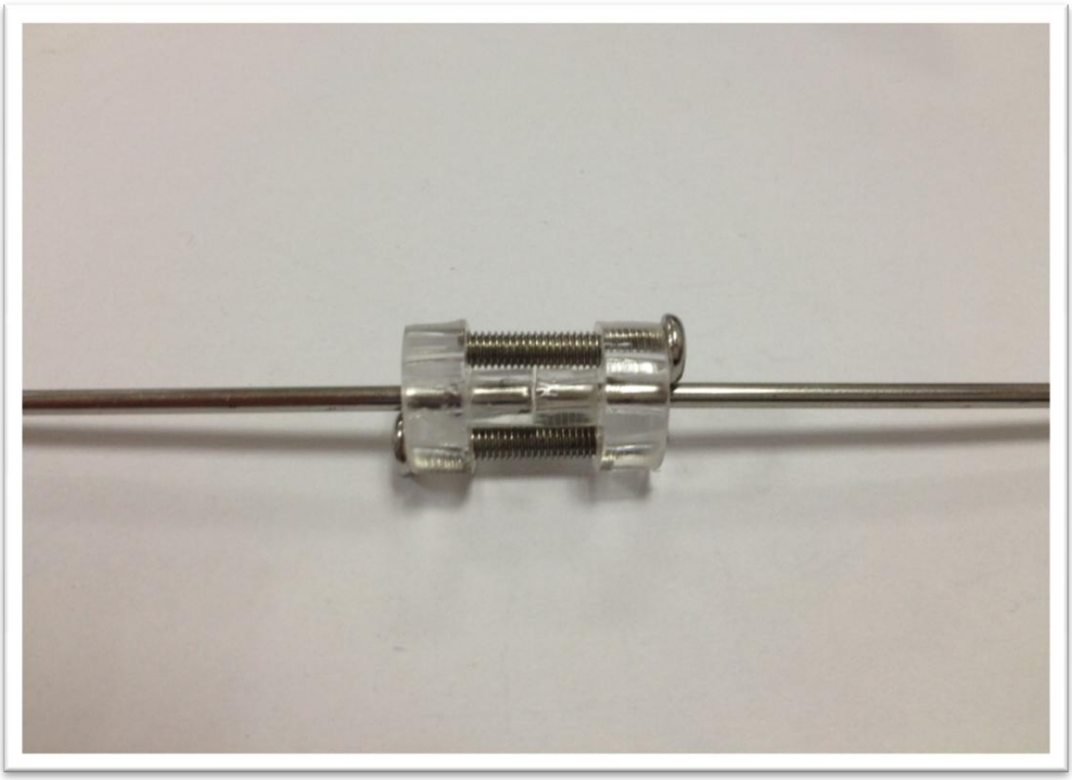
- **Mechanical hand**



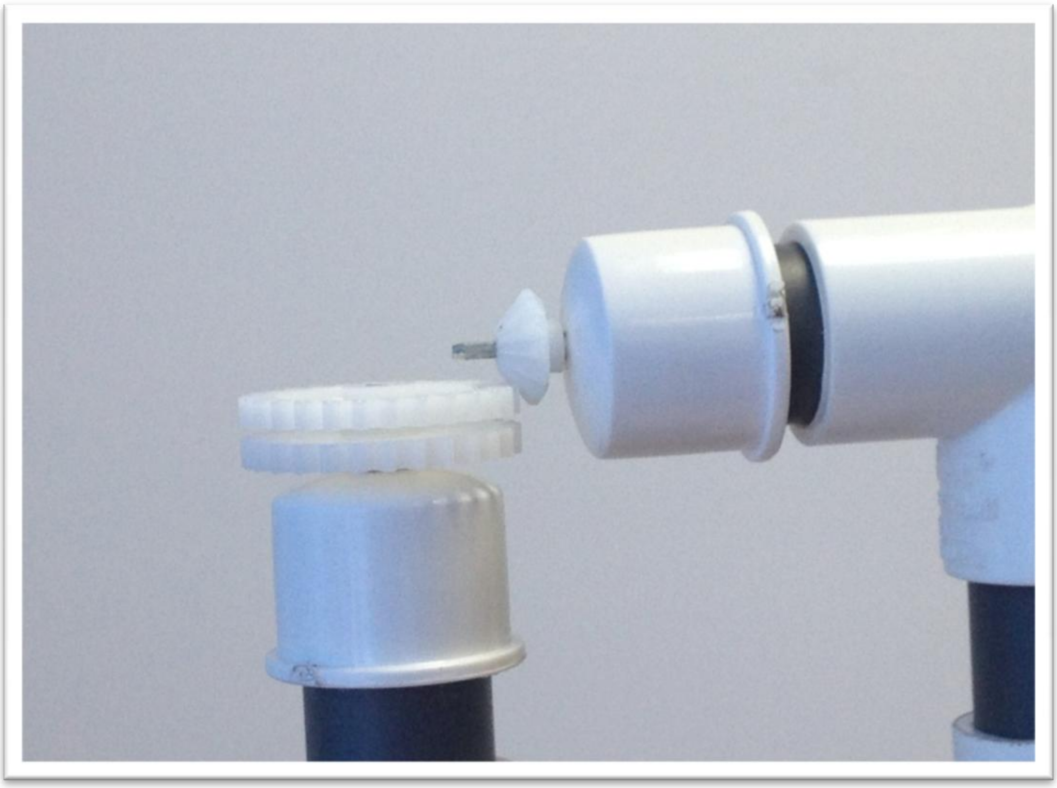
- **Mechanical arm**



- **Shaft connection**



- **Gearing**



APPENDIX V: MECHANICAL HAND

United States Patent 3927424

Application Number:

05/435214

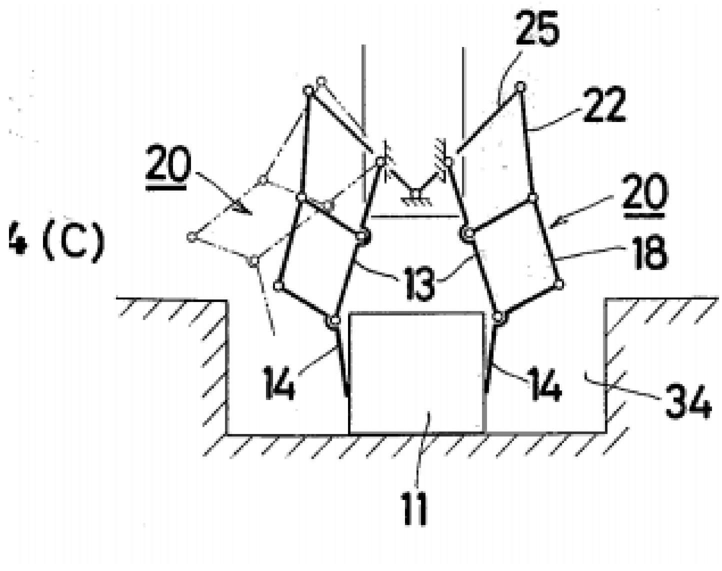
Publication Date:

12/23/1975

Filing Date:

01/21/1974

Abstract: A mechanical hand comprises a palm element and at least two finger elements and incorporates a closed link mechanism. The two finger elements are connected at their basal ends, each with a joint, the first one to the palm element and the second one to the forward end of the first finger element, respectively. The closed link mechanism is constructed of the first finger element in combination with a projecting bar which stems at a certain angle from the basal end of the second finger element and constitutes a unitary part in conjunction with the second finger element. Driving this closed link mechanism by an actuator sets the finger elements to movement. When any portion of the finger elements comes into contact with an obstacle standing in its way, the closed link mechanism begins to change its form. In consequence of this change of form, the first finger element and/or the second finger element begins to turn round the joint as a pivot and continues, while adapting the form of the mechanical hand to the immediate environment, to converge in the direction of gradually conforming to the exterior contour of an object desired to be gripped and eventually gripping the object.



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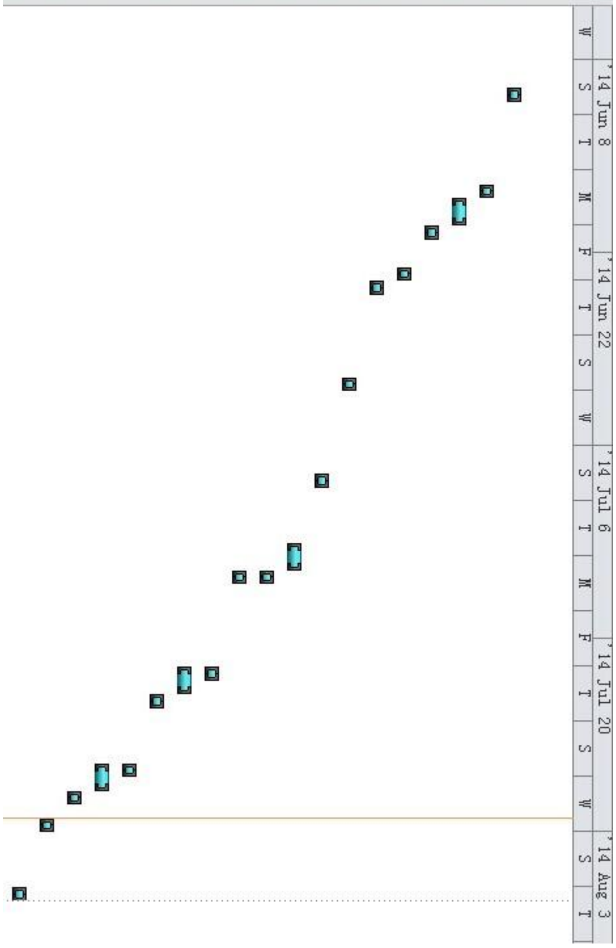
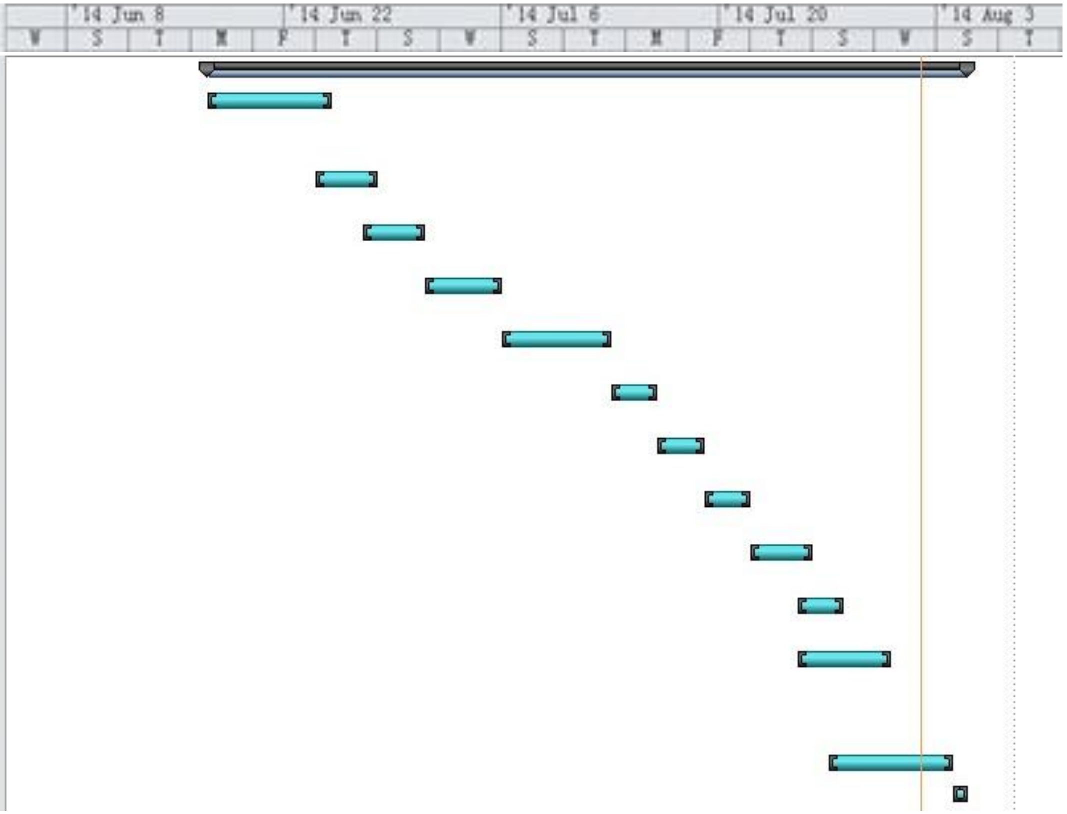
APPENDIX VI: GANTT CHART

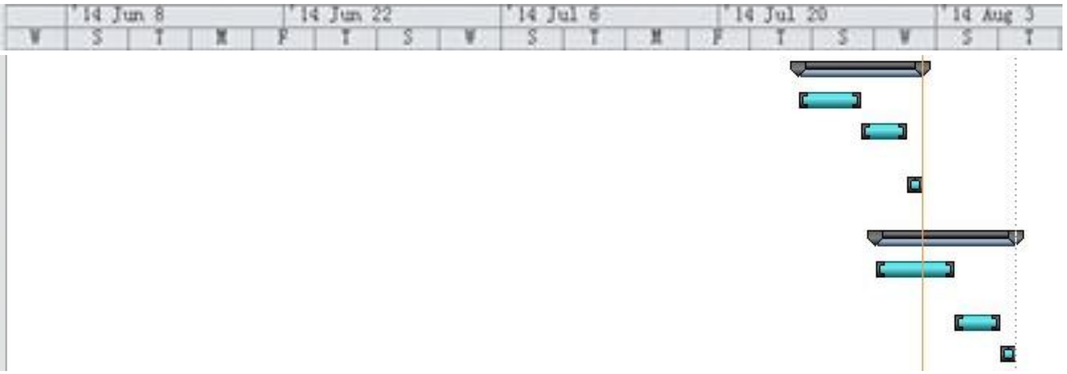
Task Name	Duration	Start	Finish
Semester project assignment	1 day	'14 May 30	'14 May 30
First team meeting	1 day	'14 Jun 10	'14 Jun 10
Second team meeting	1 day	'14 Jun 17	'14 Jun 17
Complete HW#5	2 days	'14 Jun 18	'14 Jun 19
HW#5 due	1 day	'14 Jun 20	'14 Jun 20
Exam(I)	1 day	'14 Jun 23	'14 Jun 23
Third team meeting	1 day	'14 Jun 24	'14 Jun 24
Fourth team meeting	1 day	'14 Jul 1	'14 Jul 1
Fifth team meeting	1 day	'14 Jul 8	'14 Jul 8
Complete HW#8	2 days	'14 Jul 13	'14 Jul 14
HW#8 due	1 day	'14 Jul 15	'14 Jul 15
Sixth team meeting	1 day	'14 Jul 15	'14 Jul 15
Seventh team meeting	1 day	'14 Jul 22	'14 Jul 22
Complete HW#10	2 days	'14 Jul 22	'14 Jul 23
HW#10 due	1 day	'14 Jul 24	'14 Jul 24
Eighth team meeting	1 day	'14 Jul 29	'14 Jul 29
Complete HW#11	2 days	'14 Jul 29	'14 Jul 30
HW#11 due	1 day	'14 Jul 31	'14 Jul 31
Ninth team meeting	1 day	'14 Aug 2	'14 Aug 2
Exam(II)	1 day	'14 Aug 7	'14 Aug 7



Task Name	Duration	Start	Finish
Second project	**35 days**	**'14 Jun 17**	**'14 Aug 4**
Search for relevant information	6 days	'14 Jun 17	'14 Jun 24
Come up with functions needed	4 days	'14 Jun 24	'14 Jun 27
Determine the design	2 days	'14 Jun 27	'14 Jun 30
Complete project design(CAD and UG)	5 days	'14 Jul 1	'14 Jul 5
Buy and cut materials needed	7 days	'14 Jul 6	'14 Jul 12
Manufacture the first prototype	3 days	'14 Jul 13	'14 Jul 15
Modify the first prototype	3 days	'14 Jul 16	'14 Jul 18
Draw CAD and UG for final design	2 days	'14 Jul 19	'14 Jul 21
Buy and cut materials needed	4 days	'14 Jul 22	'14 Jul 25
Manufacture final design	2 days	'14 Jul 25	'14 Jul 27
Make videos and pictures needed for presentation and final report	4 days	'14 Jul 25	'14 Jul 30
Practice operation	7 days	'14 Jul 27	'14 Aug 3
Game day	1 day	'14 Aug 4	'14 Aug 4



Task Name	Duration	Start	Finish
Presentation	**6 days**	**'14 Jul 25**	**'14 Aug 1**
Make PPT	2 days	'14 Jul 25	'14 Jul 28
Practice presentation	3 days	'14 Jul 29	'14 Jul 31
Project presentation	1 day	'14 Aug 1	'14 Aug 1
Project report	**7 days**	**'14 Jul 30**	**'14 Aug 7**
Write the first draft	4 days	'14 Jul 30	'14 Aug 3
Modify the draft	3 days	'14 Aug 4	'14 Aug 6
Final report due	1 day	'14 Aug 7	'14 Aug 7



APPENDIX VII: MINUTES

Minutes 1

Group: Group 14 (VM250)

Time: June 10th, 2014, 14:00 -- 15:00

Location: Timo Cafe

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1.Get to know to each other.

2.Initial discussion about Project 1 (multi-functional flash disk)

3.Initial discussion about Project 2 (mechanical hands)

Results:

1.Initial decision on Project 1:

a. Function: watch, light, maybe including MP3

b. Fancy appearance, compact size, simple design, easy fabrication

c. Wear on the wrist

2. Initial design for Project 2:

a. Use clamps to hold the string

b. Clamp be able to rotate along its axis

c. Use gears for transmission

3. Mission: Shen Junjie& Chu Bei: Detail design of Project 2

Huang Jianchi: Draw draft of Project 1

Liu Hanyang& Shen Yang: Get familiar with knots;

About next meeting:

1. Time: June 17^{th}, 2014, 14:00

2. Issues to be discussed: CAD drawing of Project 1;

Initial design of Project 2

Minutes 2

Group: Group 14 (VM250)

Time: June 17th , 2014

Location: ME Laboratory on the 4th floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1.Have a discussion about the final idea of project1.

2.Search information about project 2.

Results:

1,Allocate the task of drawing the sketch of project 1 to Huang Jianchi.

2.Allocate the task of buying two basic product on Taobao to Chubei.

About next meeting:

1. Time: June 24th , 2014, 14:00

2. Issues to be discussed: Finish UG drawing of project 1;

   Further improvement of the design of Project 2

Minutes 3

Group: Group 14 (VM250)

Time: June 24th , 2014, 14:00 -- 15:00

Location: ME Laboratory on the 4th floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1. Final discussion about Project 1 (multi-functional flash disk)

2. Tentative design of Project 2 (mechanical hands)

Results:

1. Final decision on Project 1:

    a. Function: watch, light, maybe including MP3

    b. Fancy appearance, compact size, simple design, easy fabrication

    c. Wear on the wrist

2. Current design for Project 2:

    a. Use clamps to hold the string

    b. Clamp be able to rotate along its axis

    c. Use gears for transmission

3. Mission: Shen Junjie: Detail design of Project 2

Huang Jianchi: Draw draft of Project 1

Liu Hanyang& Shen Yang: Get familiar with knots;

Distinguish which can be tied by our design

Chu Bei: Purchase materials decided for Project 2

About next meeting:

1. Time: July 1st , 2014, 14:00

2. Issues to be discussed: CAD drawing of Project 1;

Further improvement of the design of Project 2

Minutes 4

Group: Group 14 (VM250)

Time: July1st, 2014, 14:00 -- 15:00

Location: ME Laboratory on the 4th floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1. Finish the design drawing of Project 1 (multi-functional flash disk)

2. Final discussion about the design of Project 2 (mechanical hands)

Results:

1.Finish the design drawing ofProject 1:

   a. Draw the design drawing ofProject 1 by UG.

2. Current design for Project 2:

   a. Determine the material of the mechanical hands

   b. Start to buy the material we need

   c. Study how to knot with mechanical hands

3. Mission: Shen Junjie: Detail design of Project 2

   Huang Jianchi: Draw draft of Project 1

   Liu Hanyang& Shen Yang: Get familiar with knots;

Distinguish which can be tied by our design

Chu Bei: Purchase materials decided for Project 2

About next meeting:

1. Time: July 8th, 2014, 14:00

2. Issues to be discussed: CAD drawing of Project 1;

Further improvement of the design of Project 2

Minutes 5

Group: Group 14 (VM250)

Time: July 8th, 2014, 14:00 -- 15:00

Location: Media classroom(2) on the 2nd floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1. Tentative design of Project 2 (mechanical hands)

Results:

1. Current design for Project 2:

    a. Add holder to make the mechanical hands steady

    b. Use gears to control the rotation of the clamp

    c. Use rubber band instead of string to control the opening of the clamp

2. Mission: Shen Junjie: Design of clamp

    Huang Jianchi: Draw ug of Project 1

    Liu Hanyang& Shen Yang: Get familiar with knots;

    Distinguish which can be tied by our design

    Chu Bei: Design of holder

About next meeting:

1. Time: July 15th, 2014, 14:00

2. Issues to be discussed: Further improvement of the design of Project 2

Minutes 6

Group: Group 14 (VM250)

Time: July 15th , 2014, 14:00 -- 15:00

Location: ME Laboratory on the 2th floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1. Material for Project 2purchase (mechanical hands)

2. Draw the UG design of Project 2 (mechanical hands)

3. Manufacture for Project 2 (mechanical hands)

Results:

1. Materials for Project 2:

a. Rubber band. We can’t buy a little rubber band on TaoBao. We should buy rubber band in some shops around school.

b. Fishing line. We find the right stuff to bug on TaoBao.

2. UG design for Project 2

a. Should be more precise.

b. The shape is done, need more details.

3. Mission: Shen Junjie: Detail design of Project 2

Huang Jianchi: Draw UG draft of Project 2

Liu Hanyang& Shen Yang: Be familiar with the knots. Choose the fitting materials for Project 2.

Chu Bei: Purchase materials decided for Project 2

About next meeting:

1. Time: July 22nd , 2014, 14:00

2. Issues to be discussed: Details design for Project 2.

Minutes 7

Group: Group 14 (VM250)

Time: July 29th , 2014, 14:00 -- 15:00

Location: ME Laboratory on the 2th floor of JI Building

Attendance: Shen Junjie, Huang Jianchi, Liu Hanyang, Shen Yang, Chu Bei

Discussion:

1. Final processing for the mechanical hands
2. Division of presentation
3. Division of report

Results:

1. The mechanical hands had been finished on August 3rd. Some inperfections were eliminated.
2. Division of presentation

   Chu bei: Imperfection & Recommendation

   Huang Jianchi: Introduction of Project 1

   Liu Hanyang: Manufacturing of Project 1

   Shen Junjie: Introduction of Project 2

   Shen Yang: Summary of Project 1 & 2 & VM250

3. Division of report

Chu bei: Problem Definition & Brainstorm of Project 2

Huang Jianchi: All UG works and Material Selection of Project 1

Liu Hanyang: Cost Analysis

Shen Junjie: Manufacturing of Project 2 & Revision

Shen Yang: Abstract & Introduction & Conclusion & Brainstorm of Project 1