Global Product Structure and Engineering Design

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- Part 2: Review on the engineering design methodology
- Part 3: An engineer's dream and life

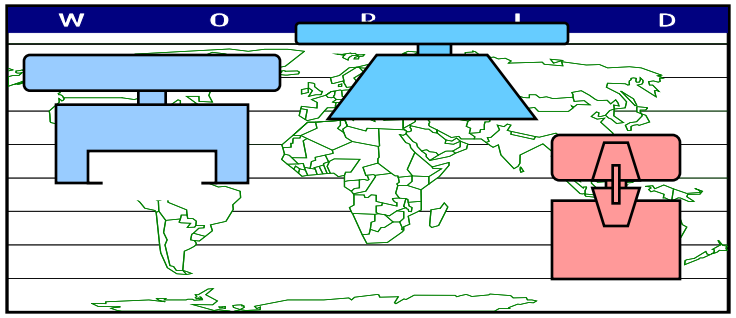
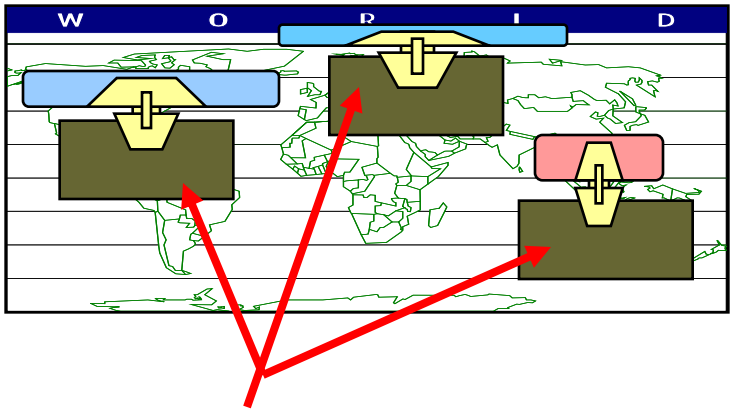
Part 1:
Structure of global products

A *global* product is …

- A product which is sold worldwide.

A global product is classified into the *dedicated* or *platform* product.

- **According to the existence of the core element:**

dedicated product	*platform* product
	
No core element exists among product models sold in different countries	A core element exists among product models sold in different countries

Dedicated products

- **Products produced in variations, tailored according to the local needs**

Canada

- Extra-large capa.
- Heavy duty
- Porcelain Basket
- Knit cycle

Brazil

- Internal heater
- Intelligent soak
- Glass lid

Hong Kong

- Anti-crease control
- Noise insulation
- Foam control
- Imbalance control

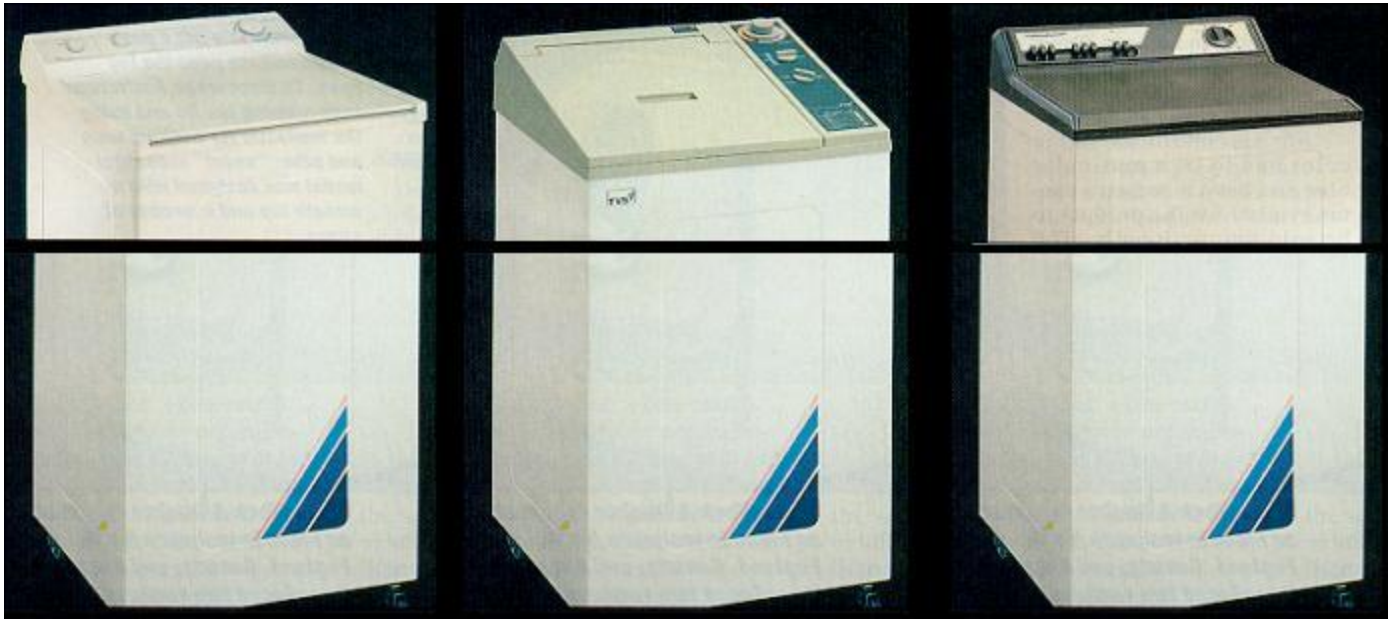
U.K.

- Front loading.
- Variable drying timer
- Vent free condenser drying

Platform products

- **Consist of**
  - **a core element or invariant element, and**
  - **other elements changed by local needs.**

Mexico version Indian version Brazilian version



Elements by local needs

A core element

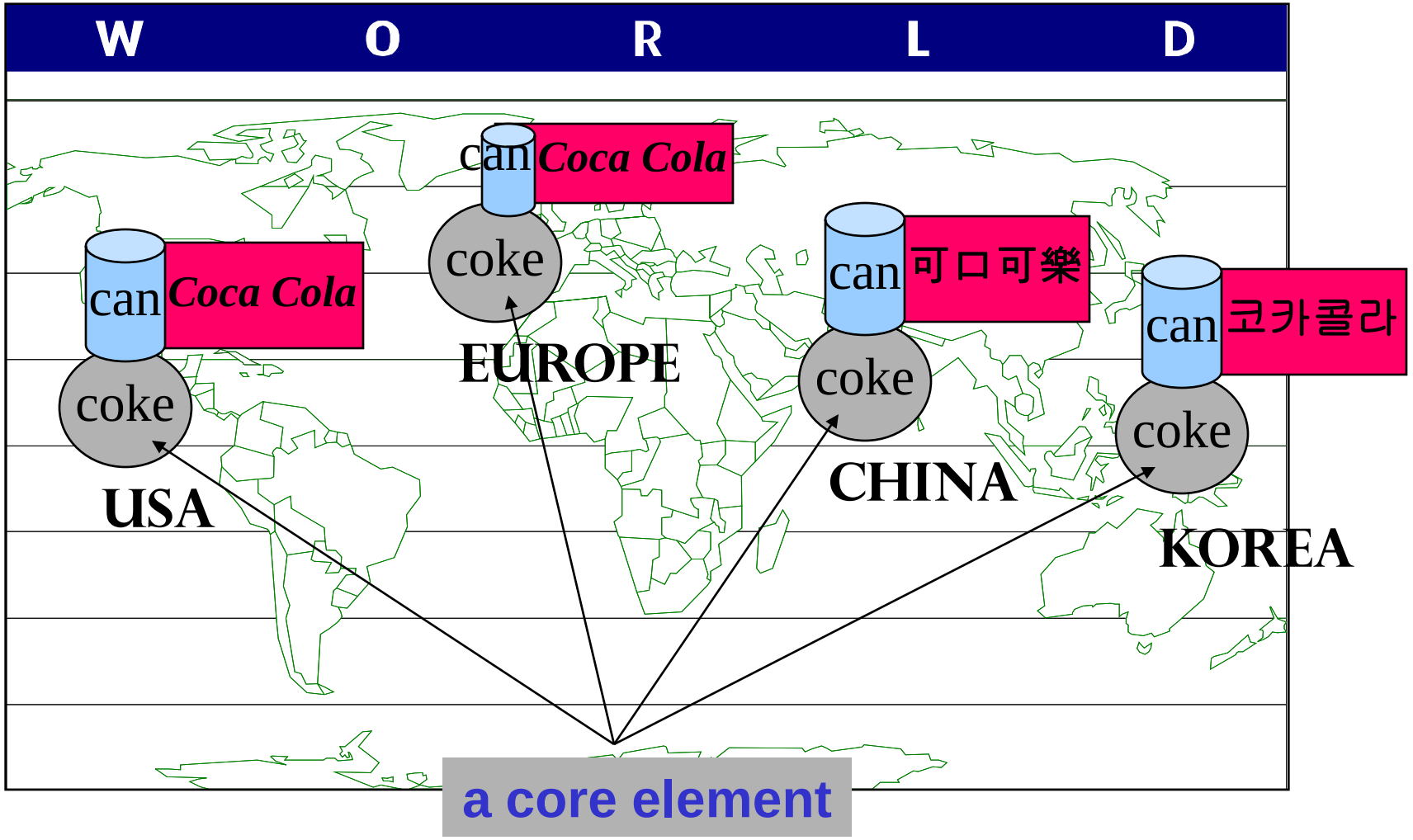
Why platform product?

- To sustain the merit of mass production by mass producing the core elements
  - Still possible to save time and cost for developing various models for worldwide markets.

➔ Lower sales price per each product

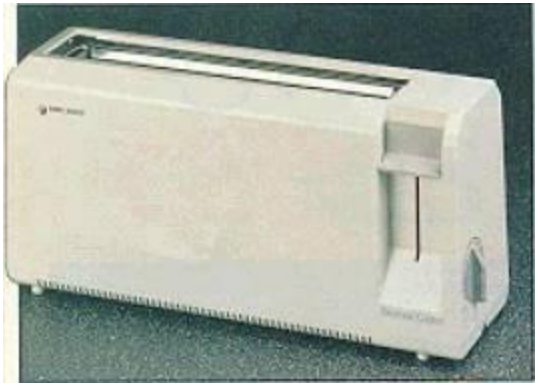
➔ Flexibility for designing next models

'*Coca Cola*' is a global platform product.



Black & Dekker's Appliances

- **A global toaster of the platform structure**
  - **U.S. market**
    - **Used for relatively thin bread**
    - **Two slots**
  - **European market**
    - **Bread is frequently too wide.**
    - **It has to accommodate one or two slices of bread.**
    - **One large slot**



➔ The core element is the main body containing the heating unit.

Honda's *World Car* project – Accord

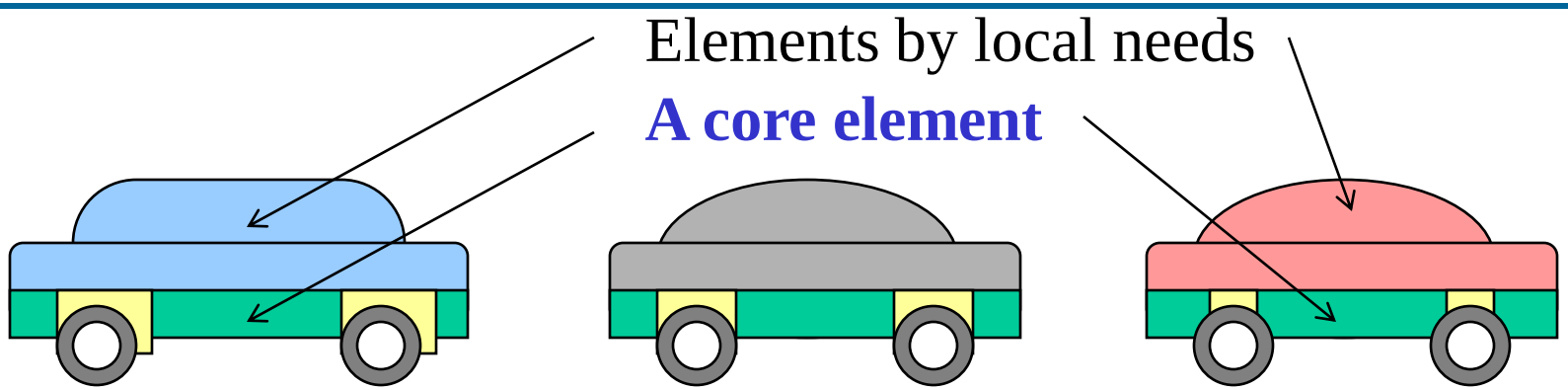
- **Variation of local needs**
  - **U.S. market : Big family car matching Ford Taurus in interior roominess, lots of compartments for maps and cups**
  - **European market : Short and narrow body, expected to feature the stiff and sporty ride for providing better handling on narrow roads**
  - **Japanese market : Stylish, jazzy, sportier compact body aiming at young professionals packed with high-tech feature such as a navigation system**

One model doesn't fit all worldwide.

- Then, designing a different model for each market (dedicated product)?
  - Ford Motor Co. spent $2.8 billion for redesigning the 1996 Taurus model
  - Too much cost and lead-time for developing three different models
  - Will loose the merit of mass production

➔ The sales price and the time-to-market of each model will increase.

Honda's challenge



U.S. market

Accord Sedan DX

L: 4,796
W: 1,786
H: 1,445
WB: 2,715
TW: 1,554/1,534
E: 2.3 *l* / SOHC

Japanese market

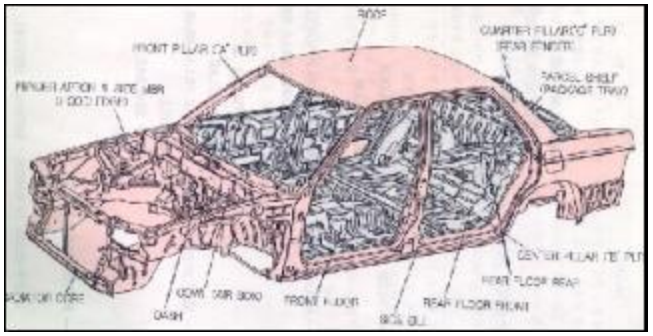
Accord SiR

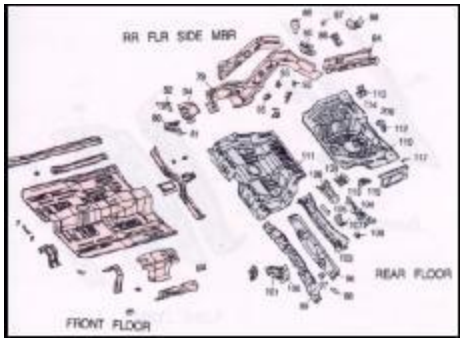
L: 4,635
W: 1,695
H: 1,420
WB: 2,665
TW: 1,480/1,480
E: 2.0 *l* / DOHC

(Note) WB = wheelbase TW = track width (front/rear)

The core element of Honda *Accord*

- **A flexible underbody**
  - **that can be expanded or shortened by using three sets of the special brackets for the U.S., Japan and European models**





A underbody (front body + rear body + side member)

Wheelbase: US Accord = 2,715 (sedan), 2,670 (coupe)
Japanese Accord = 2,665 (SiR and wagon)
Track width: US Accord = 1,554/1,534 (sedan and coupe)
Japanese Accord = 1,480/1,480 (SiR), 1,490/1,490 (wagon)

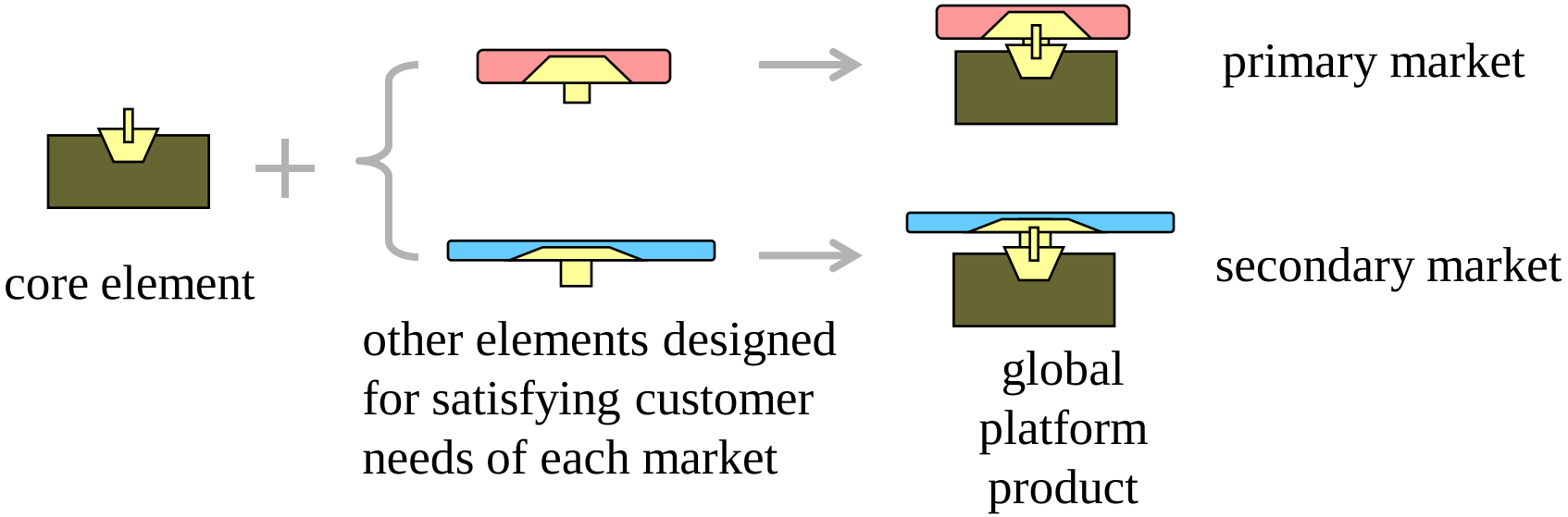
Pricing punch by Honda *Accord*

- **Flexible global platform** idea gave birth to three distinct *Accord*s
  - that cost 20% less than the single Accord developed 4 years ago
  - Savings: $1,200 per car

Model	Power	Base Price	Passenger Space
98 Honda Accord	V6, 3.0*l*, 200hp	$21,500	101.7 cubic feet
98 Toyota Camry	V6, 3.0*l*, 194hp	$22,978	97.9 cubic feet
98 Ford Taurus	V6, 3.0*l*, 200hp	$19,290	101.5 cubic feet

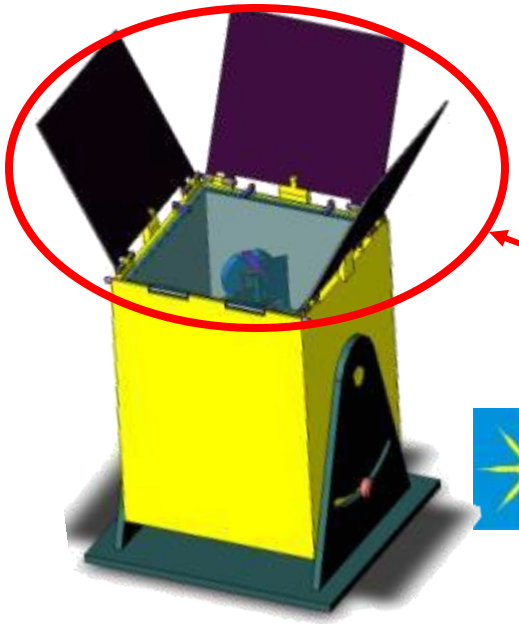
We recommend you to design a global platform product,

- which consists of
  - a core element, and
  - the other elements changed by the needs of each market you selected.

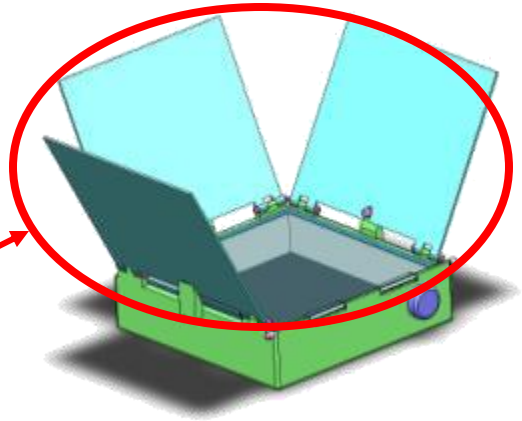


GPD design project example (1)

- **Primary market:**
  African region (Ethiopia)
  - **sterilization of syringes for immunization and therapeutic purposes**
- **Secondary market:**
  USA
  - **Boiling water by solar energy**



core element



Sunitizer TeamOne

Sustainable Stove

GPD design project example (2)

Educational Toy

- **Primary market:**
  USA
  - **Hand-cranking**
  - **Various contents**
- **Secondary market:**
  African region
  - **Hand-cranking**
  - **Educating HIV/AIDS**

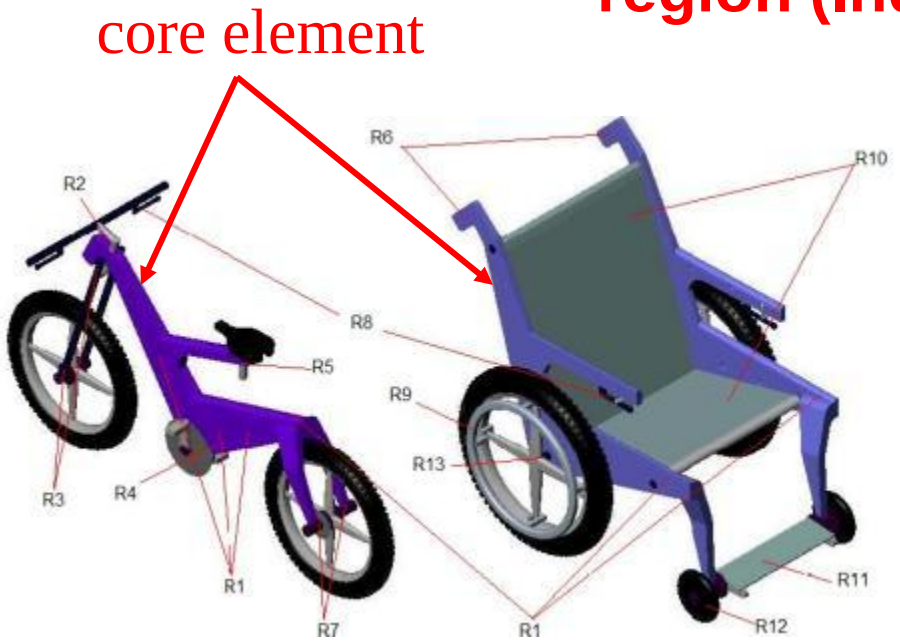
core element:
main body

Contents are different.

GPD design project example (3)

Transformable Bike

- **Primary market:**
  European region (Germany)
- **Secondary market:**
  African and developing Asian region (India)



Part 2: Review on the engineering design methodology

(especially, on the systematic *conceptual design*)

A good reference on engineering design methodology

Pahl, G. and Beitz, W.

Engineering Design – A Systematic Approach

Springer, London, 1996.

- Technical University of Berlin -

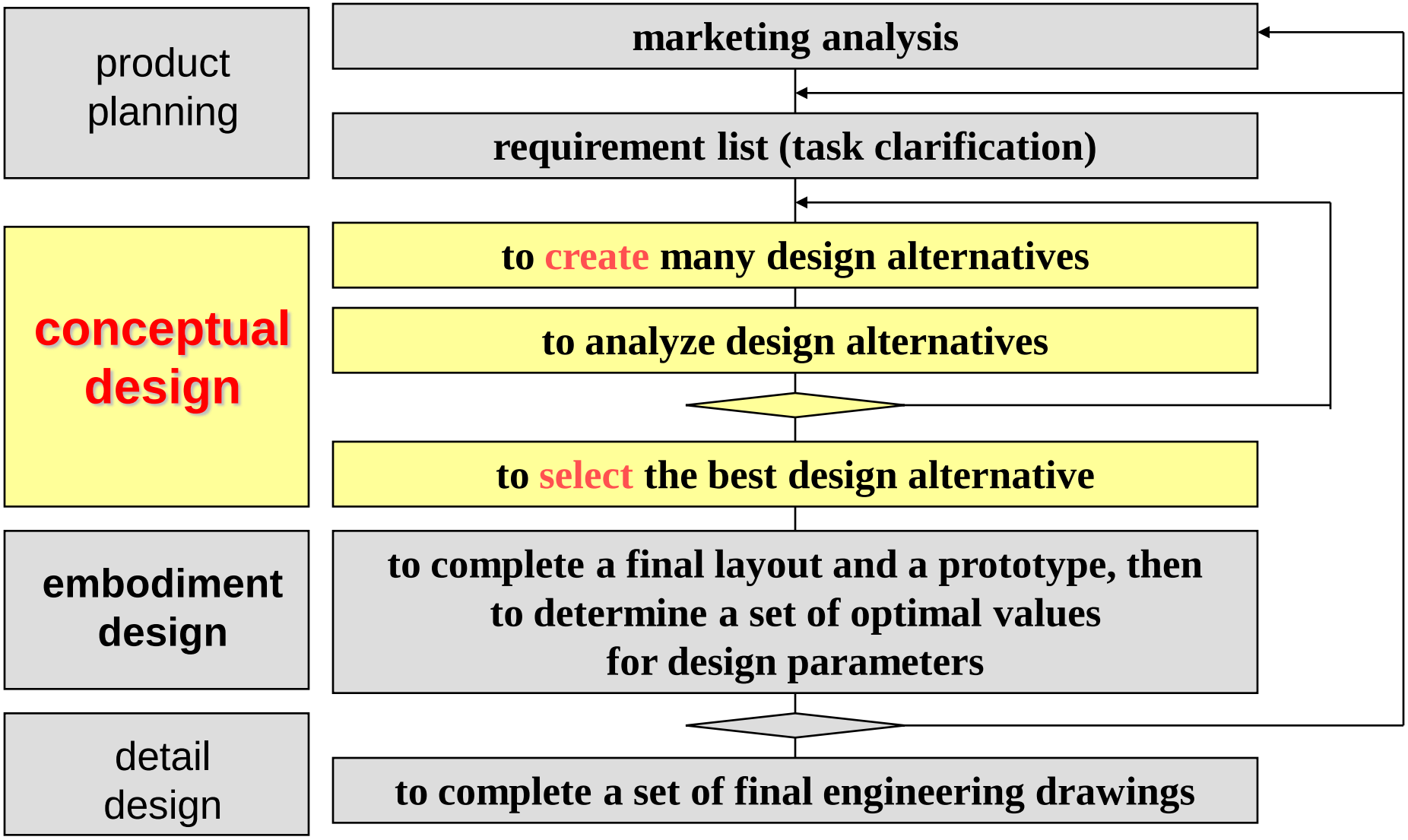
Engineering design is

To create as many as design alternatives to the given customer requirements by applying scientific and engineering knowledge,

then, to select a best one among them, and finally, to optimize it,

within the constraints set by material, technological, economic, legal, environmental and human-related considerations.

Steps of engineering design



Conceptual design

- **Input : a requirements list**
- **What to do : create as many as design alternatives, and then, select a best one among them.**
- **Output : a best design alternative**

Steps of the conceptual design

data

definition

creation

evaluation and decision

requirements list

Abstract to identify the essential problems

Establish function structures (divide it into sub-functions)

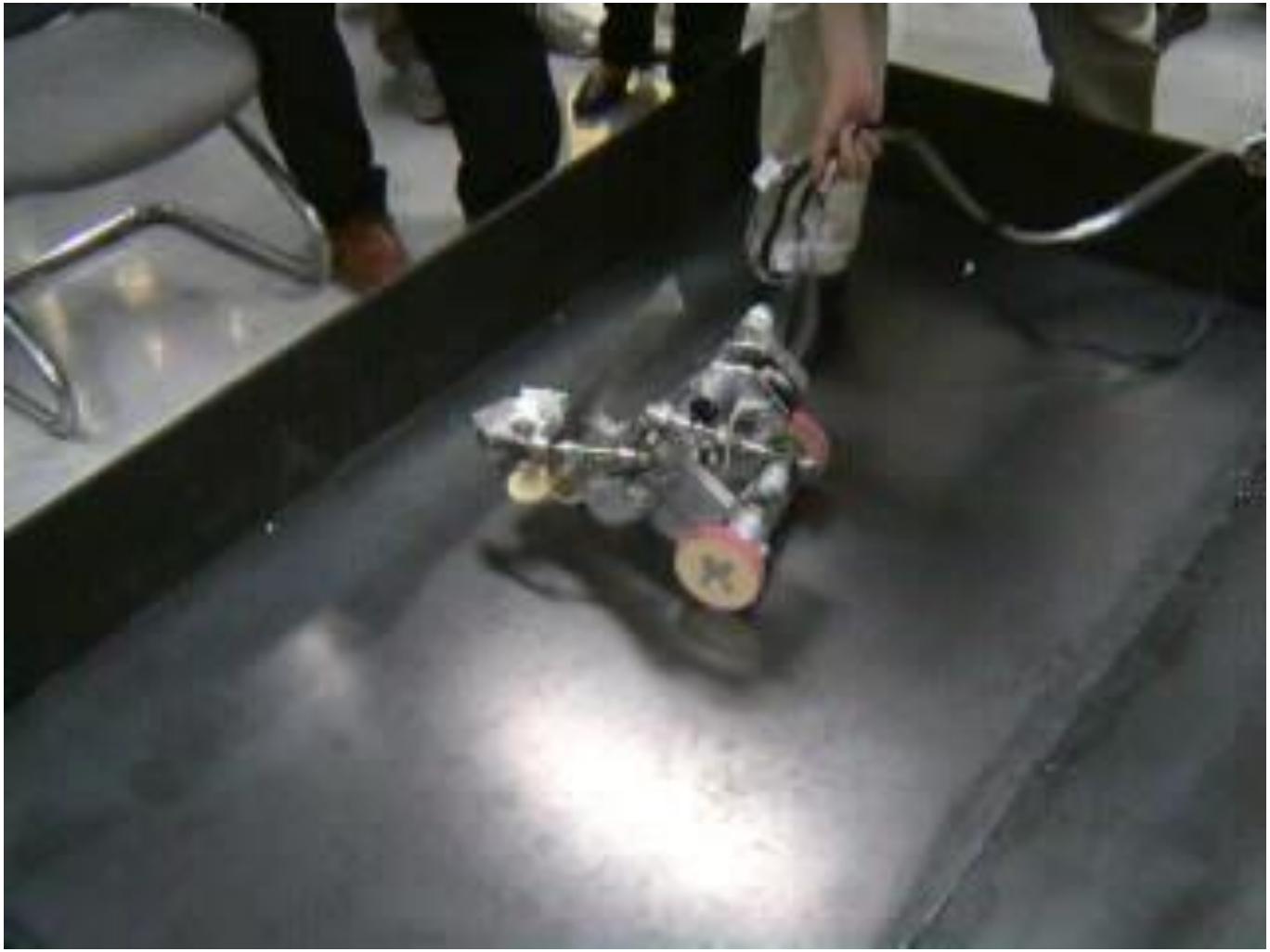
Search for working principles for each sub-functions

Integrate working principles into many design alternatives

Evaluate design alternatives based on economic/technical aspects

Select one final design alternative

A case study: To design a spider golfer
(undergraduate design project in 2004)



Conceptual design starts from the requirements list.

D: *demand*, the requirement that must be met under all circumstances.

W: *wish*, the requirement that should be taken into consideration whenever possible

user		Requirements list for project, product	issued on / page
change	D or W	requirement	responsible
Date of change	Specify if item is D or W	**functions** required by **customers.** **constraints** satisfied by the product.	Design group responsible

Requirements list for the spider golfer (1)

Marketing Engr	Director	Requirements list for Spider Golfer	2004. 9. 15.
Soo Ho Lee	Jongwon Kim		page 1/3

D/W	Required functions and constraints	
W	Geometry	The whole body of the machine should be located on the fixture (1860 x 1000mm). No constraints on the height. Within 500 x 500 x 500 mm
	Material	steel or aluminum
	Velocity	See the contest fixture (page 3), maintain average velocity so that the round trip should be done within 4 min.
	Motion	When moving on the plane floor, the forward and backward movement should be possible (max. velocity = 0.05m/sec). Steering should be also possible. The robot can proceed from the plane to the vertical surface and vice versa. The robot can move up and down the vertical surface (max. velocity = 0.02m/sec).
	Grip	The robot grips the golf ball on the fixture and stores it inside the body within 10 sec.
	Tee-off	The robot throws the ball to the desired direction within 5 sec. The shooting velocity should be fast enough to reach the goal gate, but not too fast for the camera sensing.
	Golf ball	standard mass 45.93g, diameter 41.15mm

Requirements list for the spider golfer (2)

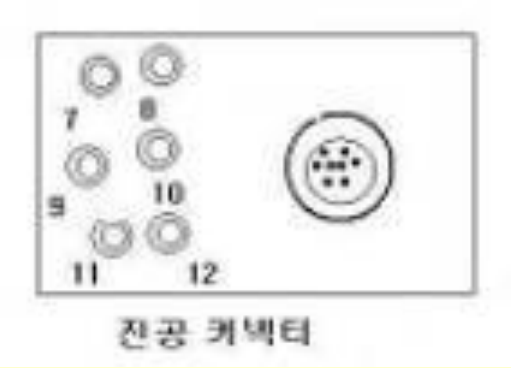
Marketing Engr	Director	Requirements list for Spider Golfer	2004. 9. 15.
Soo Ho Lee	Jongwon Kim		page 2/3

D/W	Required functions and constraints

Force The robot can resist the gravity force when moving on the vertical surface.

Energy DC 24V (4-6A)
Pneumatic source 5 kgf per square cm
Vacuum source (specification TBA)

Control Joystick signal: 4 channels
On/off signal for pneumatic and vacuum source: total 8 channels
The robot should accommodate two connectors as follows (size 40 x 40 x 70mm)

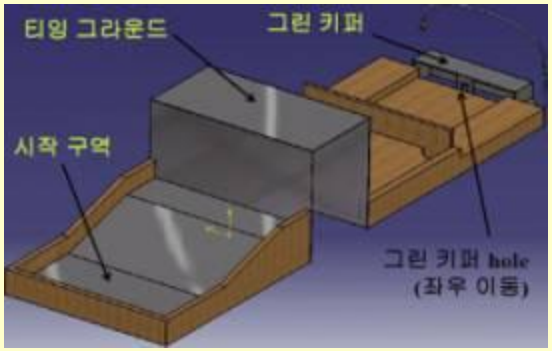


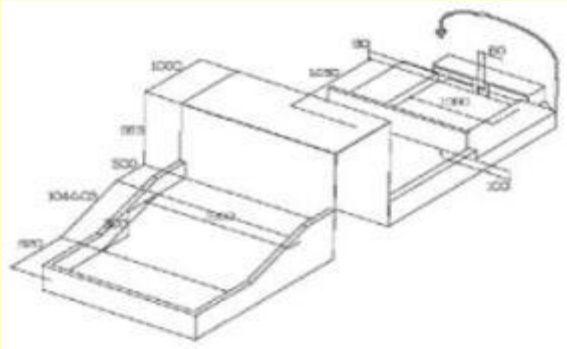
Requirements list for the spider golfer (3)

Marketing Engr	Director	Requirements list for Spider Golfer	2004. 9. 15.
Soo Ho Lee	Jongwon Kim		page 3/3

D/W	Required functions and constraints

Contest fixture





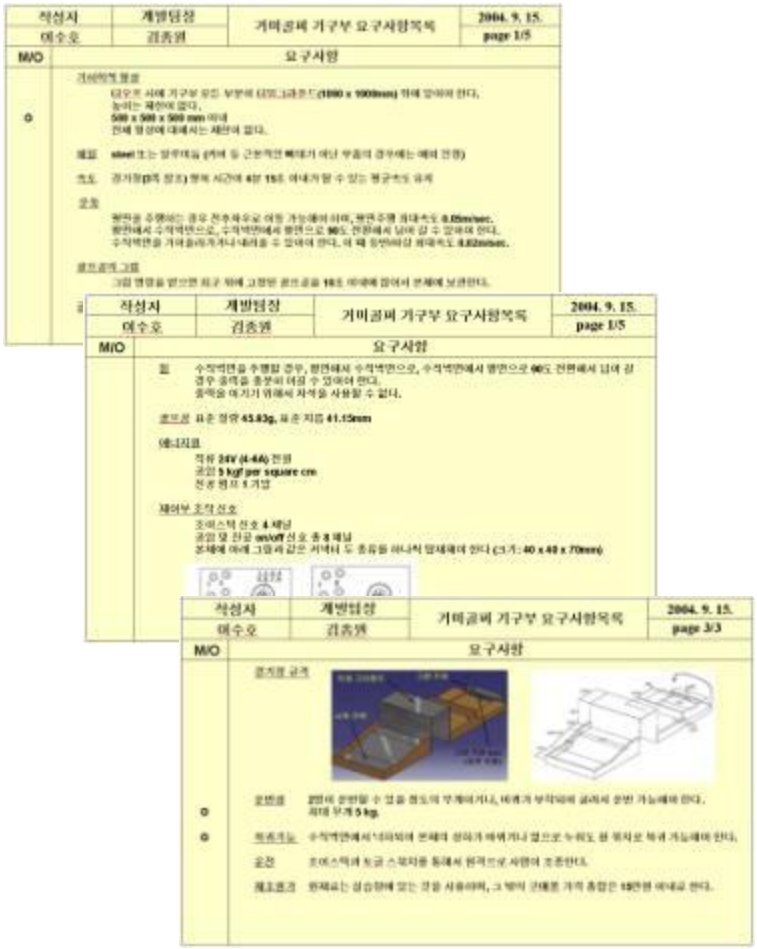
D/W		
	Mobility	One persons should be able to carry the robot.
W		Max weight 5 kg.
W	**Returning**	when it falls from the cliff and turned over, it can return to the original posture by itself.
	Operation	Remote controlled by human using joysticks and on/off switches.
	Cost	Materials are steel or aluminum stored in the shop floor. The total cost of the other machine elements purchased from outside shops must be within US$ 150.

1. Abstract to identify the essential problems

- The start point is to analyze the requirements list, and to omit requirements that have no direct relationship with the required function and essential constraints
- Then, to transform quantitative into qualitative data, and,
- To reduce them to essential statements which define the required function of the new product.

Abstraction for the spider golfer

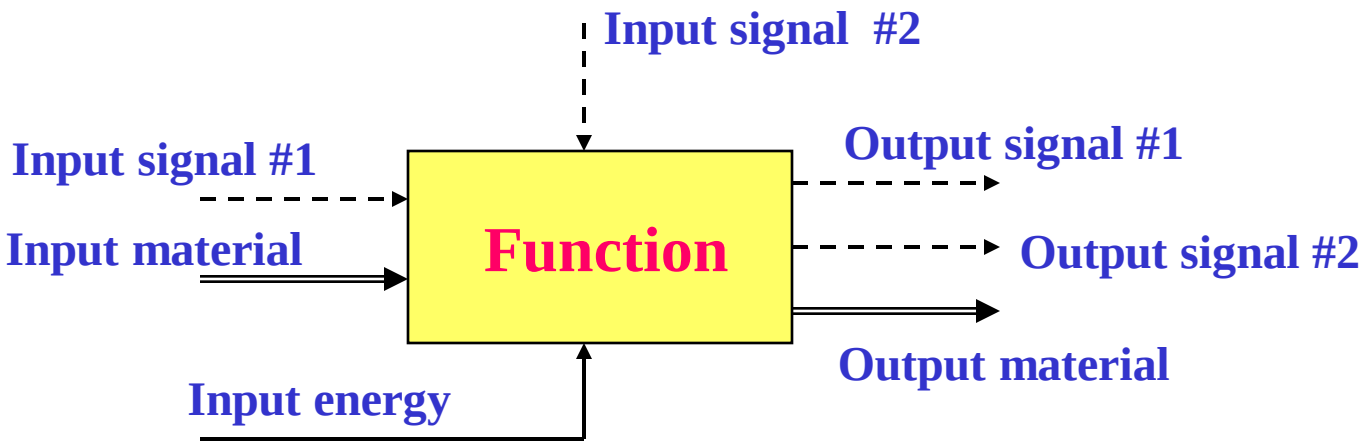
A requirements list ➔ Abstraction

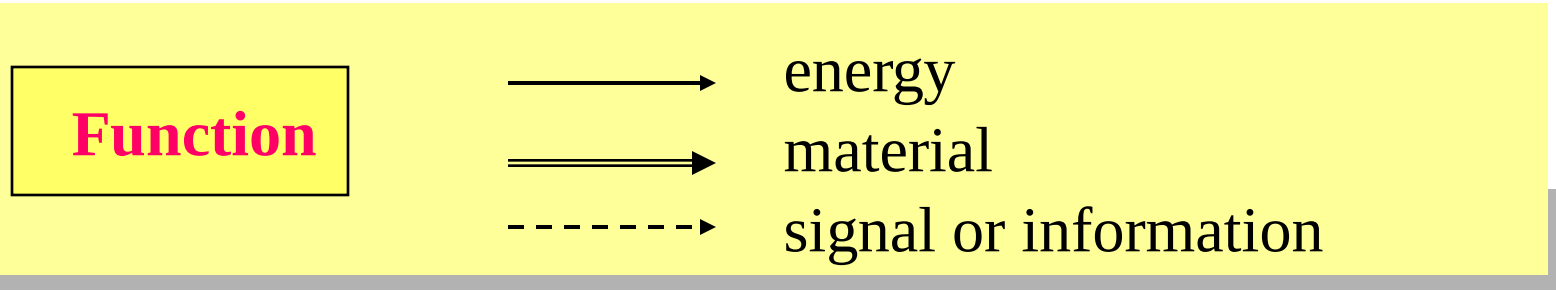


- **Basic functions**: Grip the golf ball on the fixture, move on the plane and vertical surface to reach the tee-off ground and release the ball. Then return to the starting area.
- **Essential constraints**: The robot is remotely controlled by human beings outside the contest fixture.

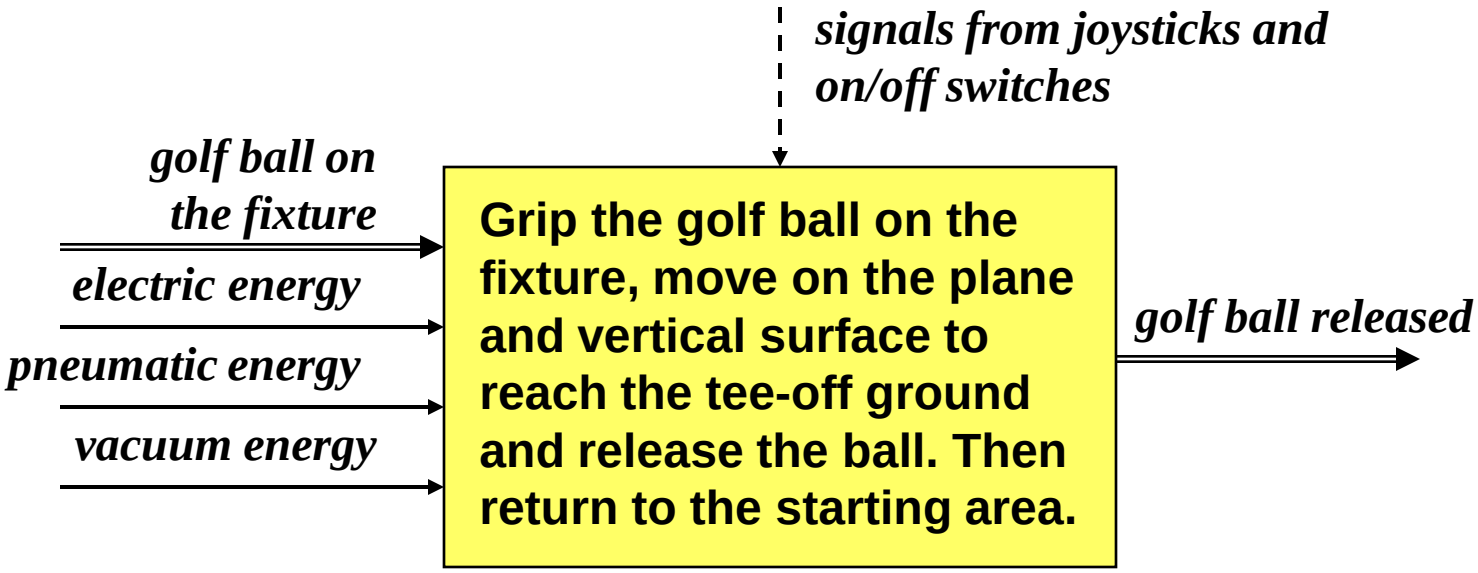
2. Establish a function structure

- **Express the abstracted problem into the function structure**
  - **“function” is described in the box.**
  - **Define input an output for each function block.**

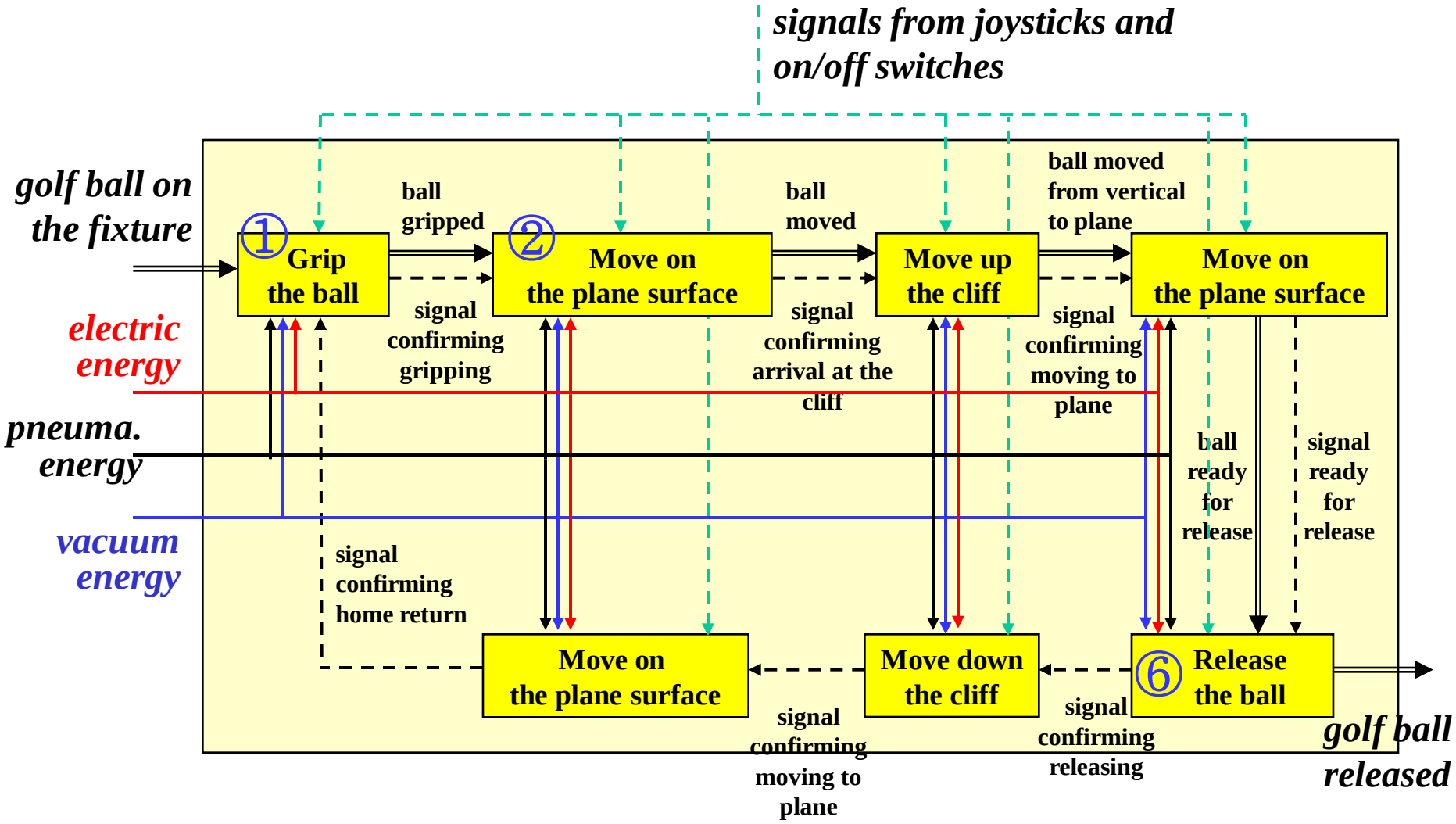




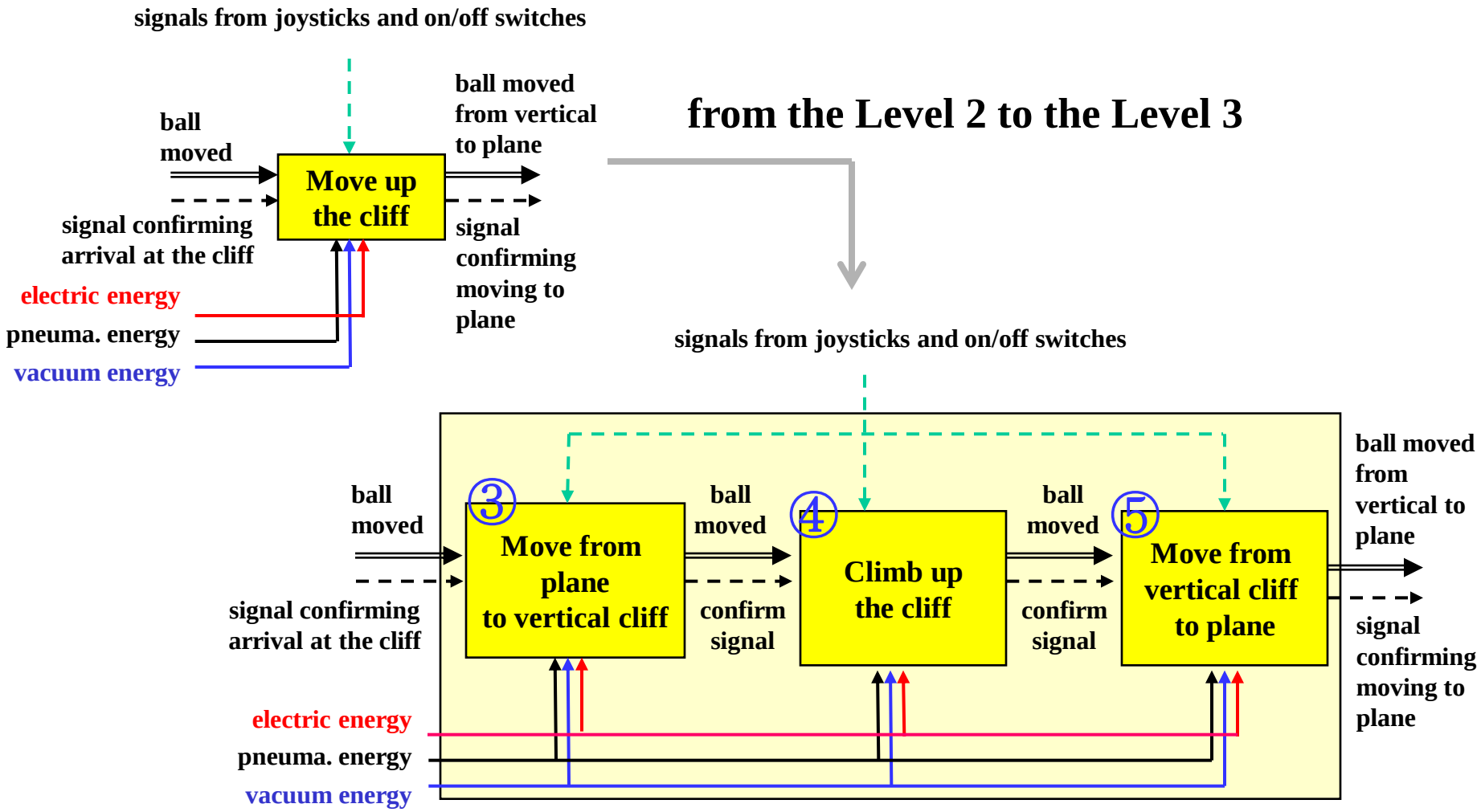
Level 1 function structure: A spider golfer



Level 2 function structure: A spider golfer



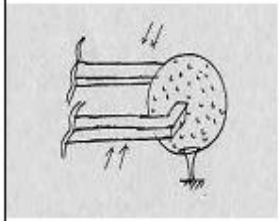
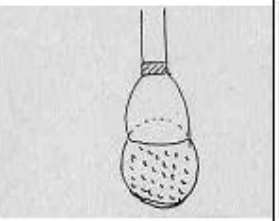
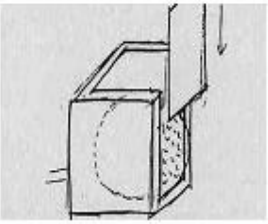
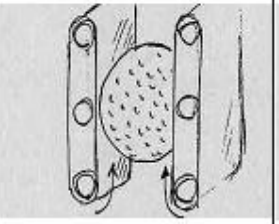
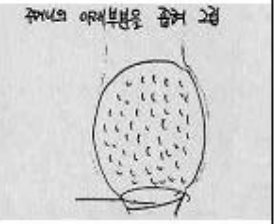
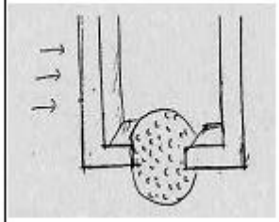
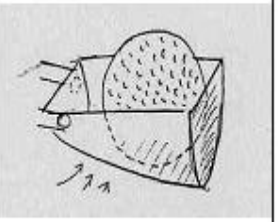
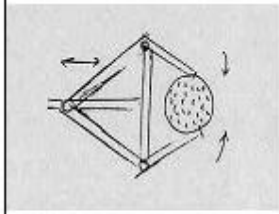
Level 3 function structure: A spider golfer



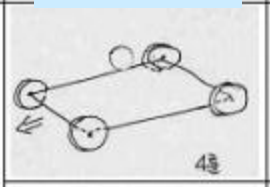
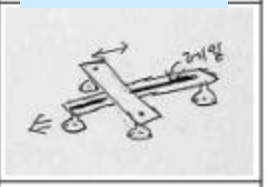
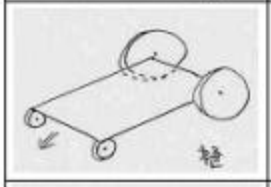
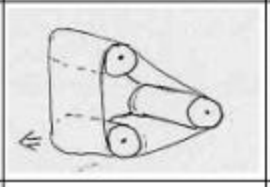
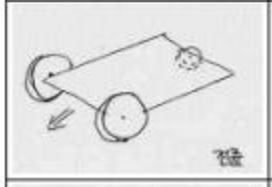
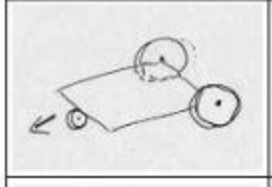
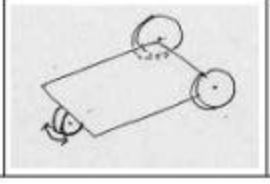
3. Search for working principles for each sub-functions

- List up the sub-functions to be realized from the functional structure.
- For each sub-function, search for the working principles which can realize the sub-function.
  - By using brainstorming
  - By referring to the previous technologies, literatures and brochures.

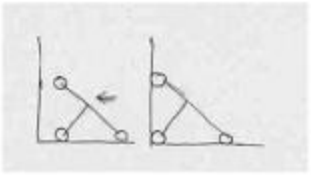
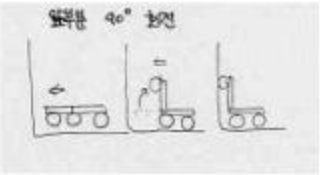
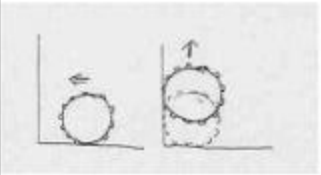
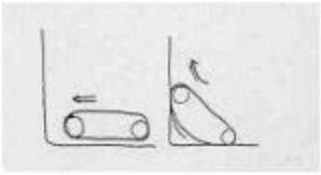
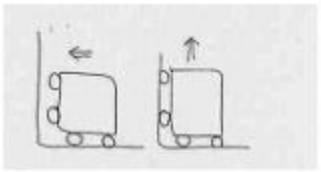
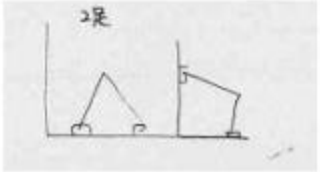
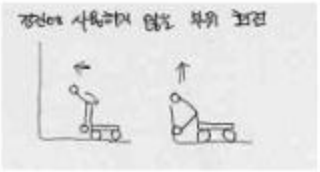
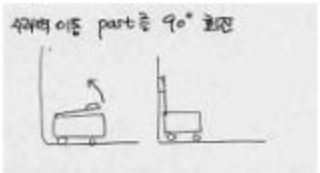
Working principle search for the sub-function #1

Sub-functions	working principle #1	working principle #2	working principle #3	working principle #4	working principle #5
	grip from both sides	grip using vacuum	grip using container	grip using caterpillar	grip using wire trap
① Grip the ball					
					
					

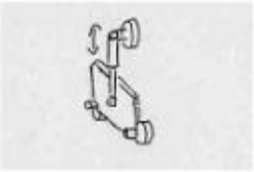
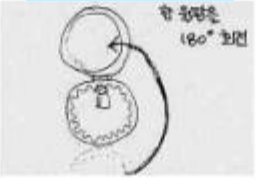
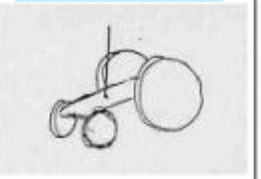
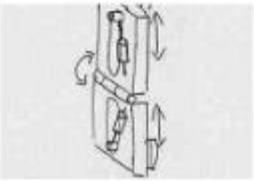
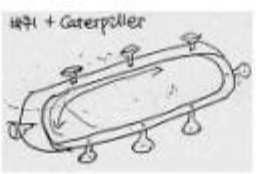
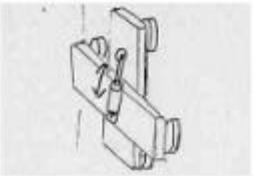
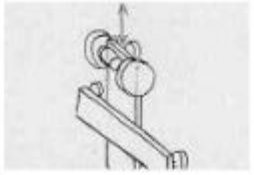
Working principle search for the sub-function #2

Sub-functions	working principle #1 move using wheels	working principle #2 move as insects	working principle #3 move like a tank	working principle #4 whole body moving	working principle #5 move using cross mech.
② Move on the plane surface					
					
					
					
					

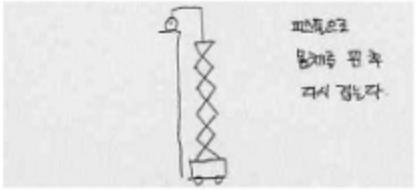
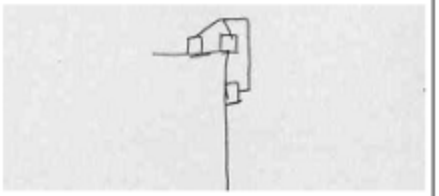
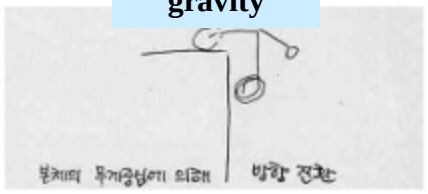
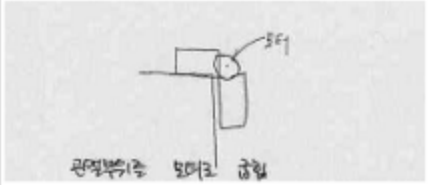
Working principle search for the sub-function #3

Sub-functions	working principle #1 one-body structure	working principle #2 two-body structure	working principle #3 move using friction wheel	working principle #4 grip using car structure
③ Move from plane to vertical cliff				
				
				
				

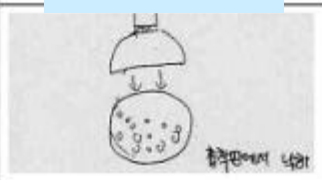
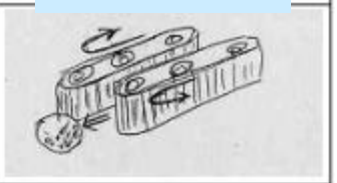
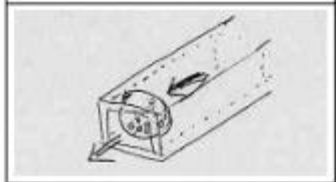
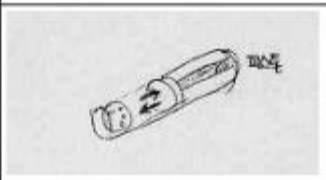
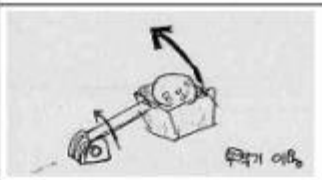
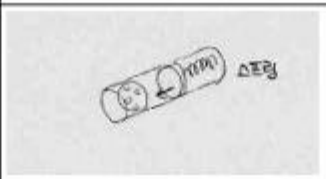
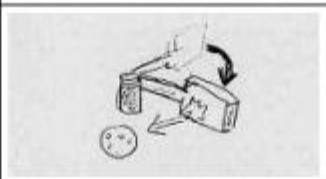
Working principle search for the sub-function #4

Sub-functions	working principle #1 piston mechanism	working principle #2 magnetic wheel	working principle #3 whole body spinning	working principle #4 crane mechanism	working principle #5 walking mechanism
④ Climb up the cliff					
					
					
					

Working principle search for the sub-function #5

Sub-functions	working principle #1	working principle #2	working principle #3
⑤ Move from vertical cliff to plane	flexible structure	+ rail structure	move as Insects
			
	working principle #4	working principle #5	working principle #6
	crane mechanism	two-body link	using gravity
			
			

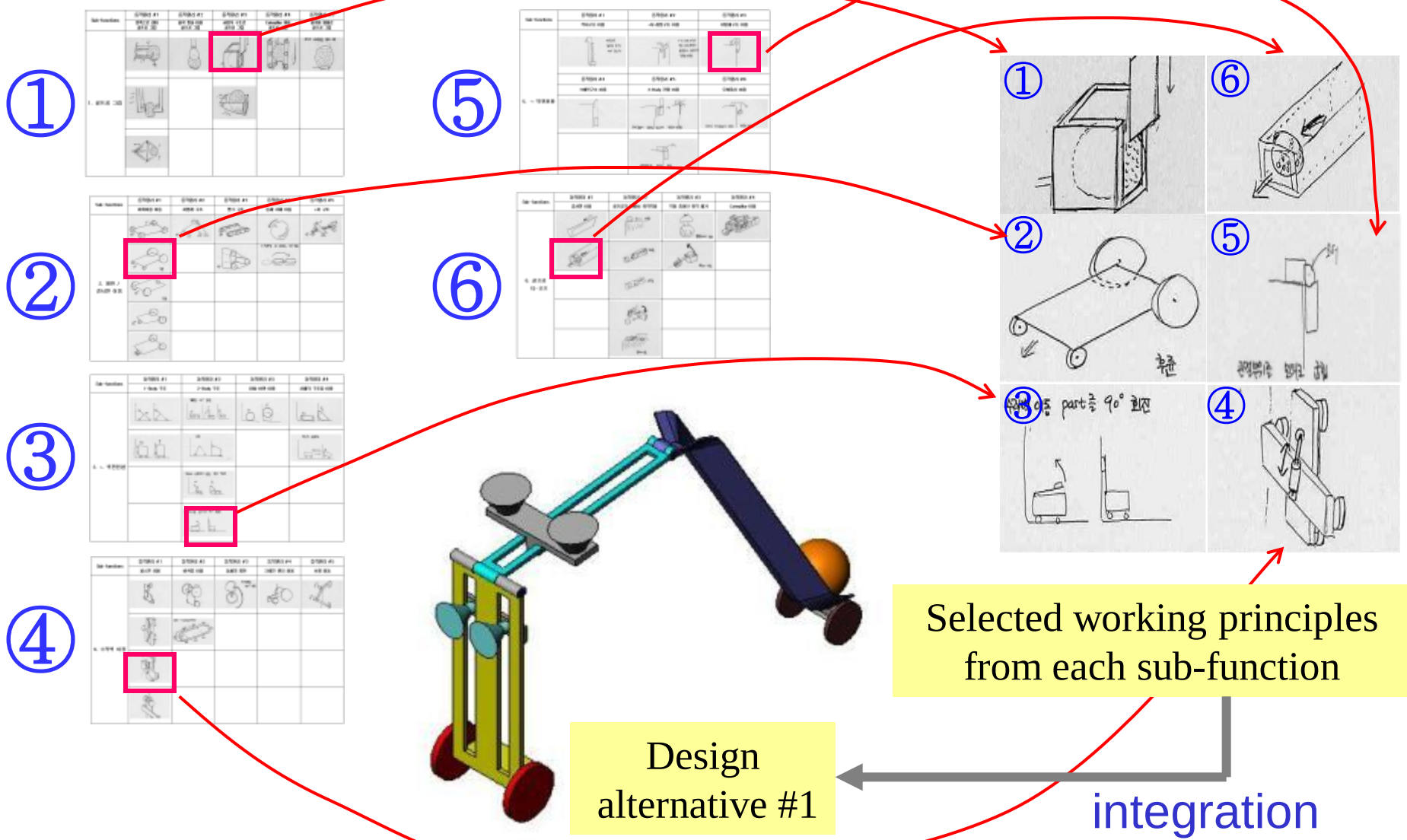
Working principle search for the sub-function #6

Sub-functions	working principle #1 inclined surface	working principle #2 push behind	working principle #3 cut out the force exerted	working principle #4 caterpillar structure
⑥ Release the ball				
				
				
				
				

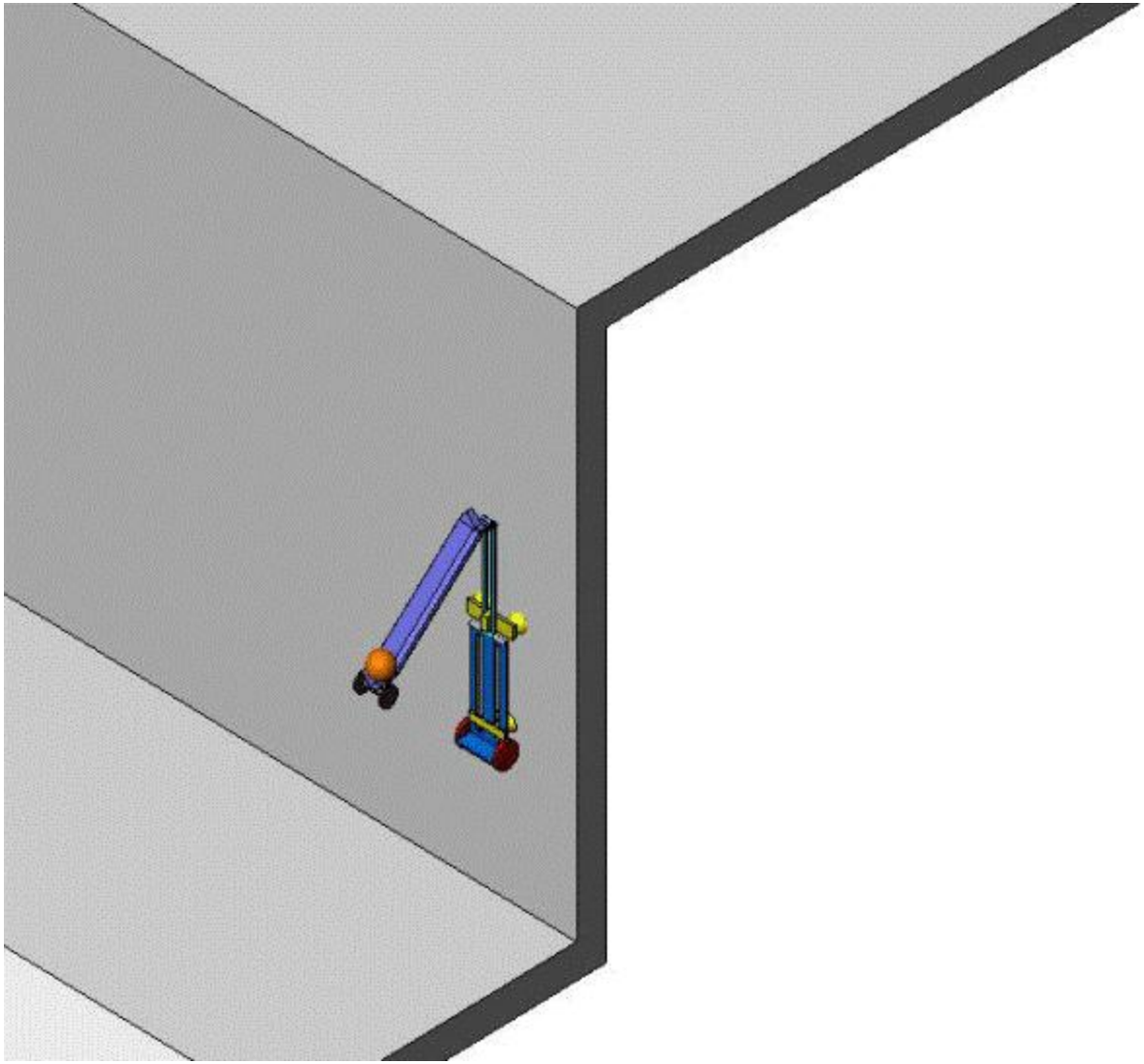
4. Create many design alternatives by using the method of combination

1. Select one working principle among the working principles that have been searched for each sub-function.
2. Then, integrate those selected working principles to obtain a design alternative.
3. Repeat the above procedure to obtain as many as design alternatives.

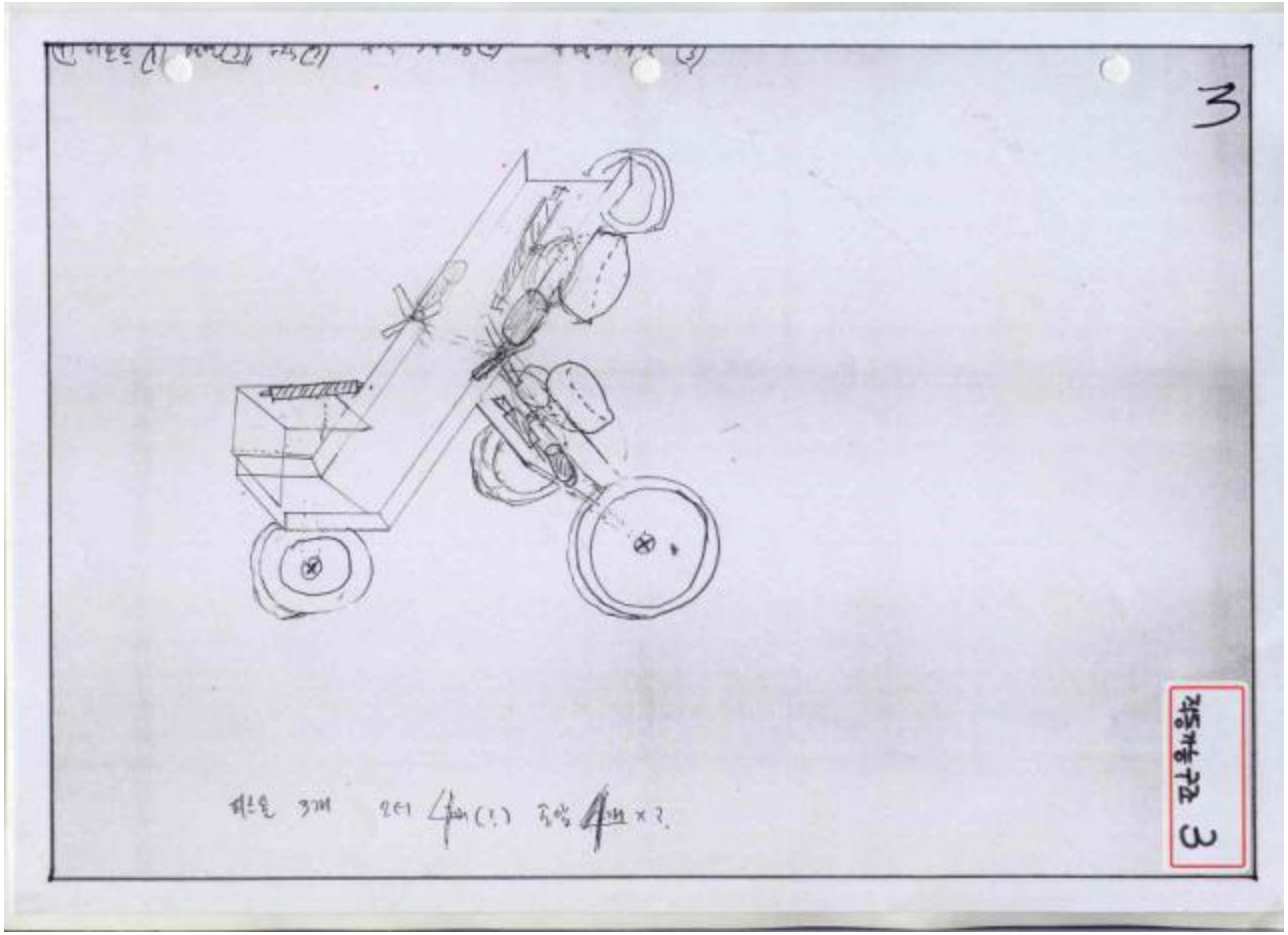
Design alternative #1

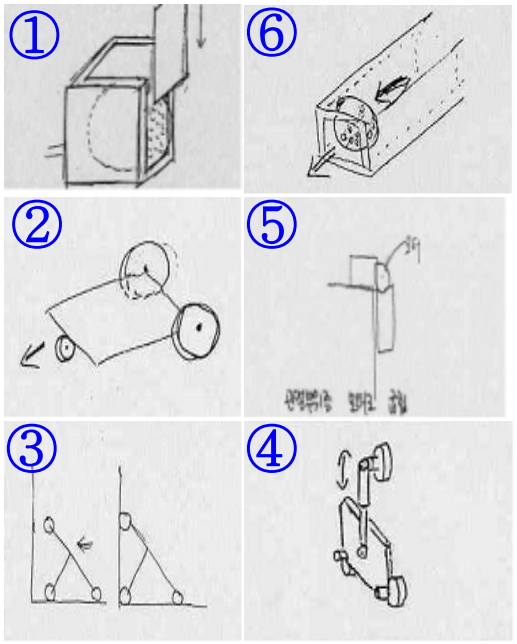


Motion check of the design alternative #1



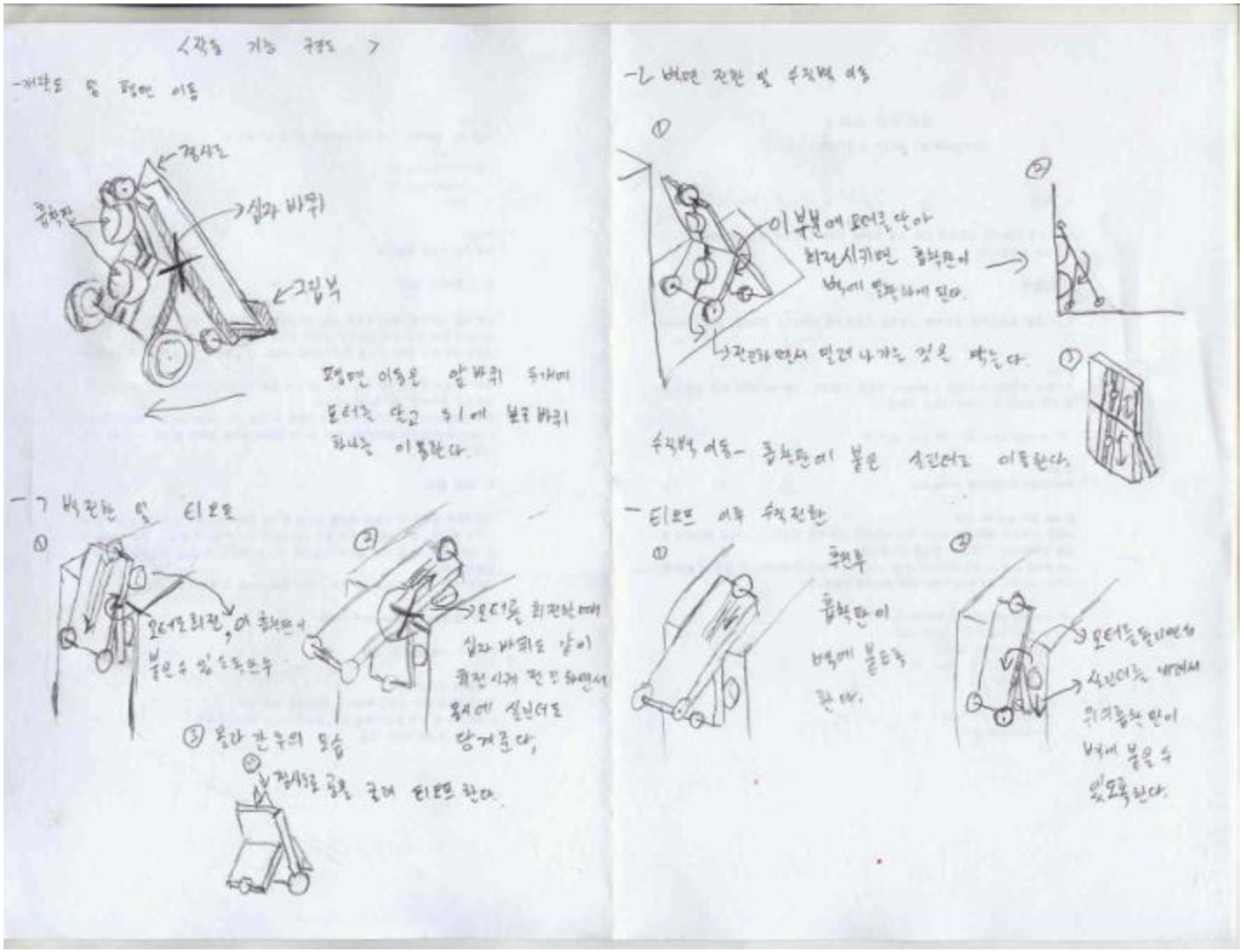
Design alternative #2



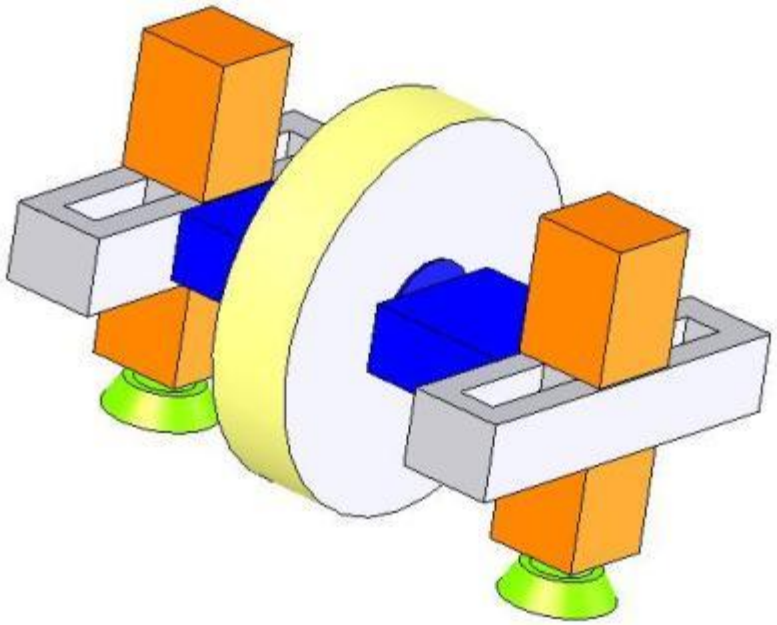


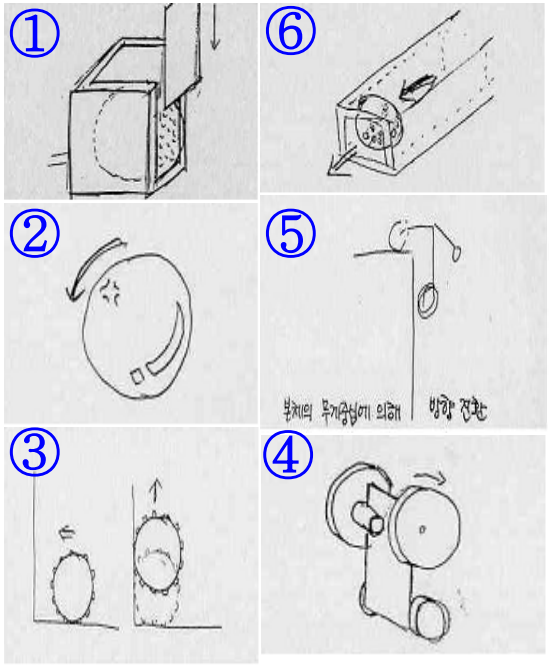
A different set of working principles is selected from each sub-function

Motion check of the design alternative #2

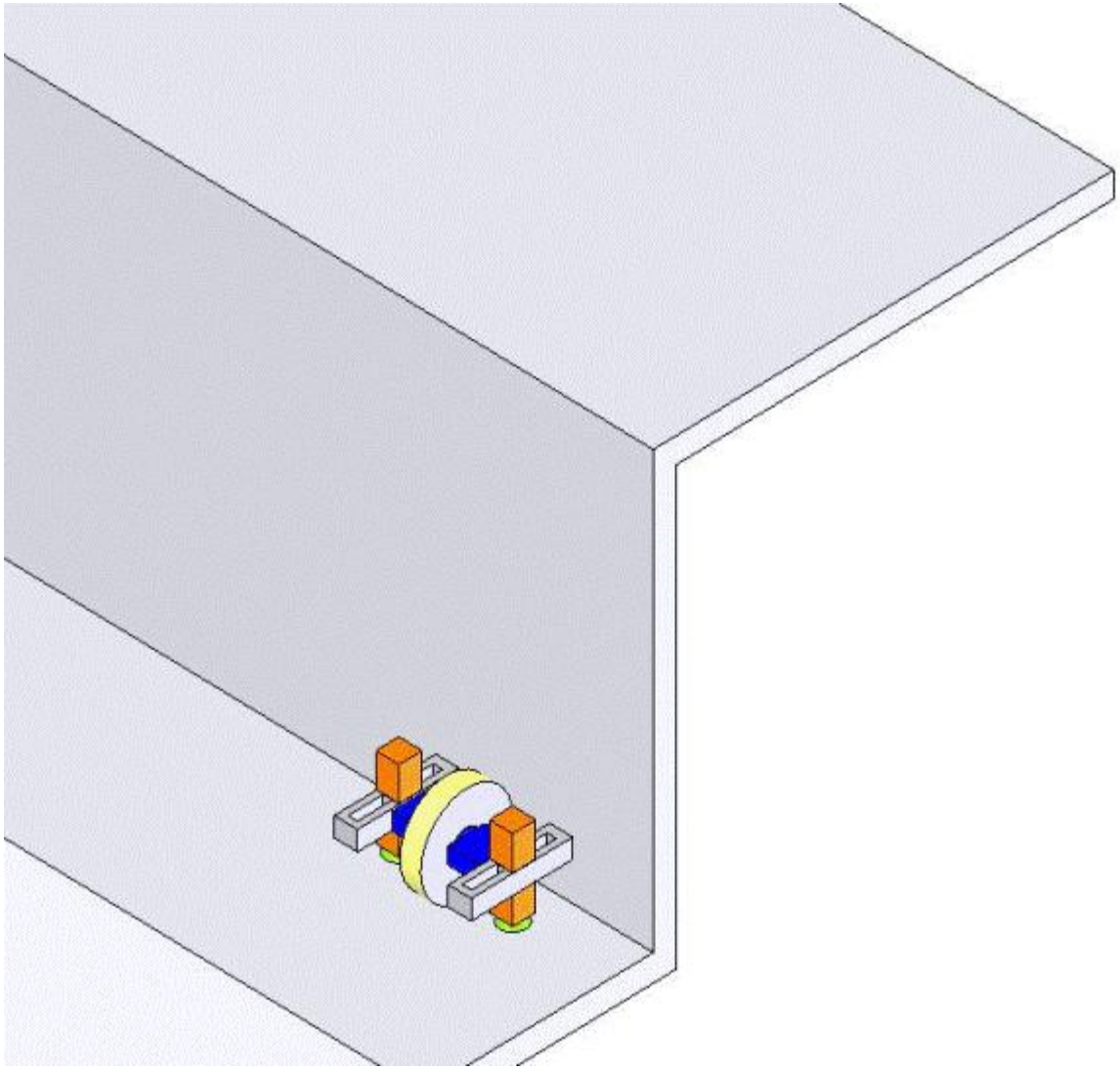


Design alternative #3

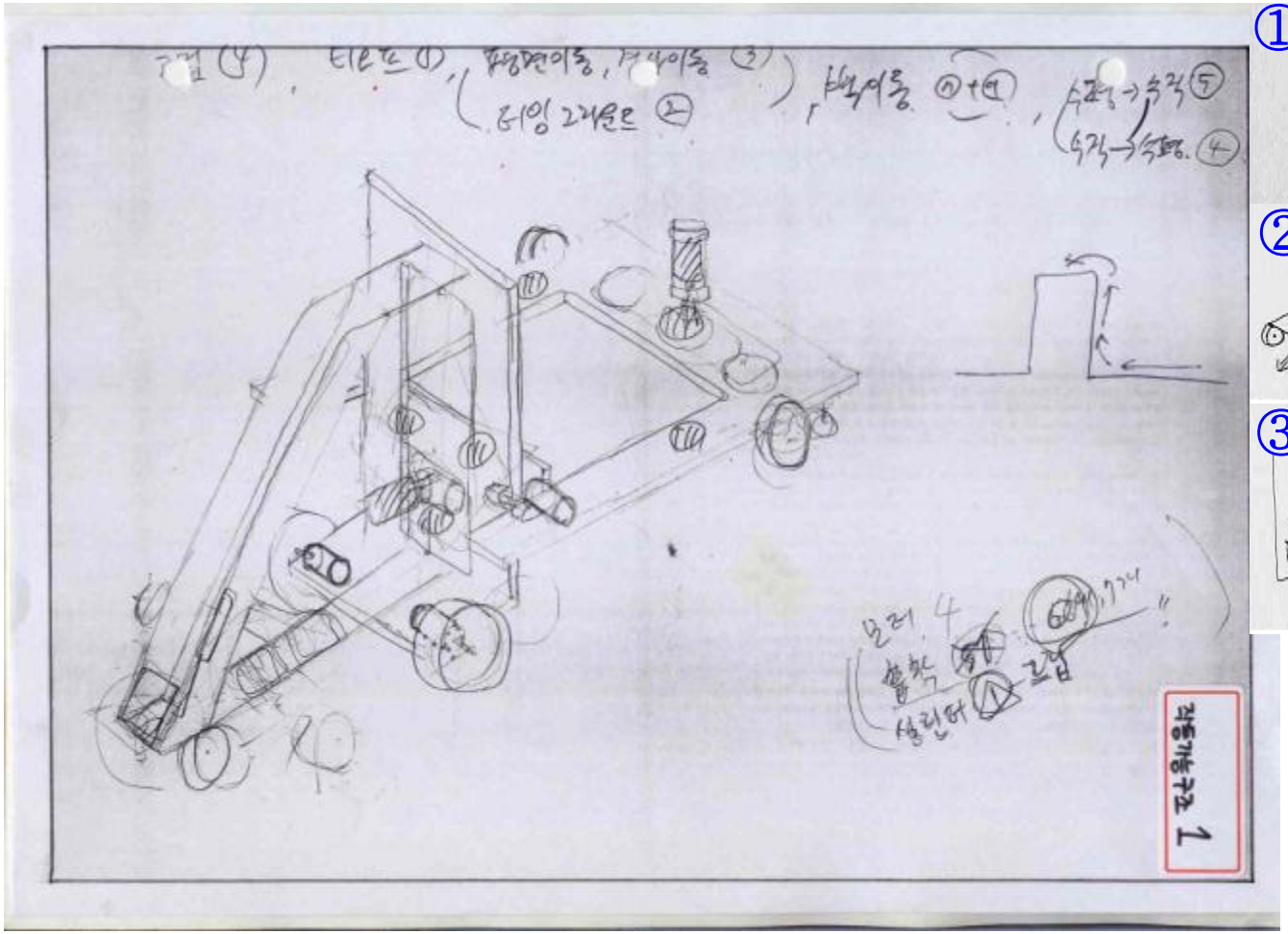


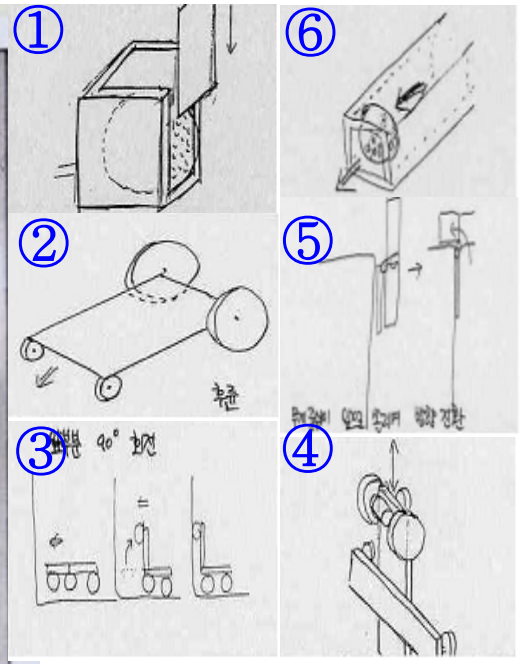


Motion check of the design alternative #3

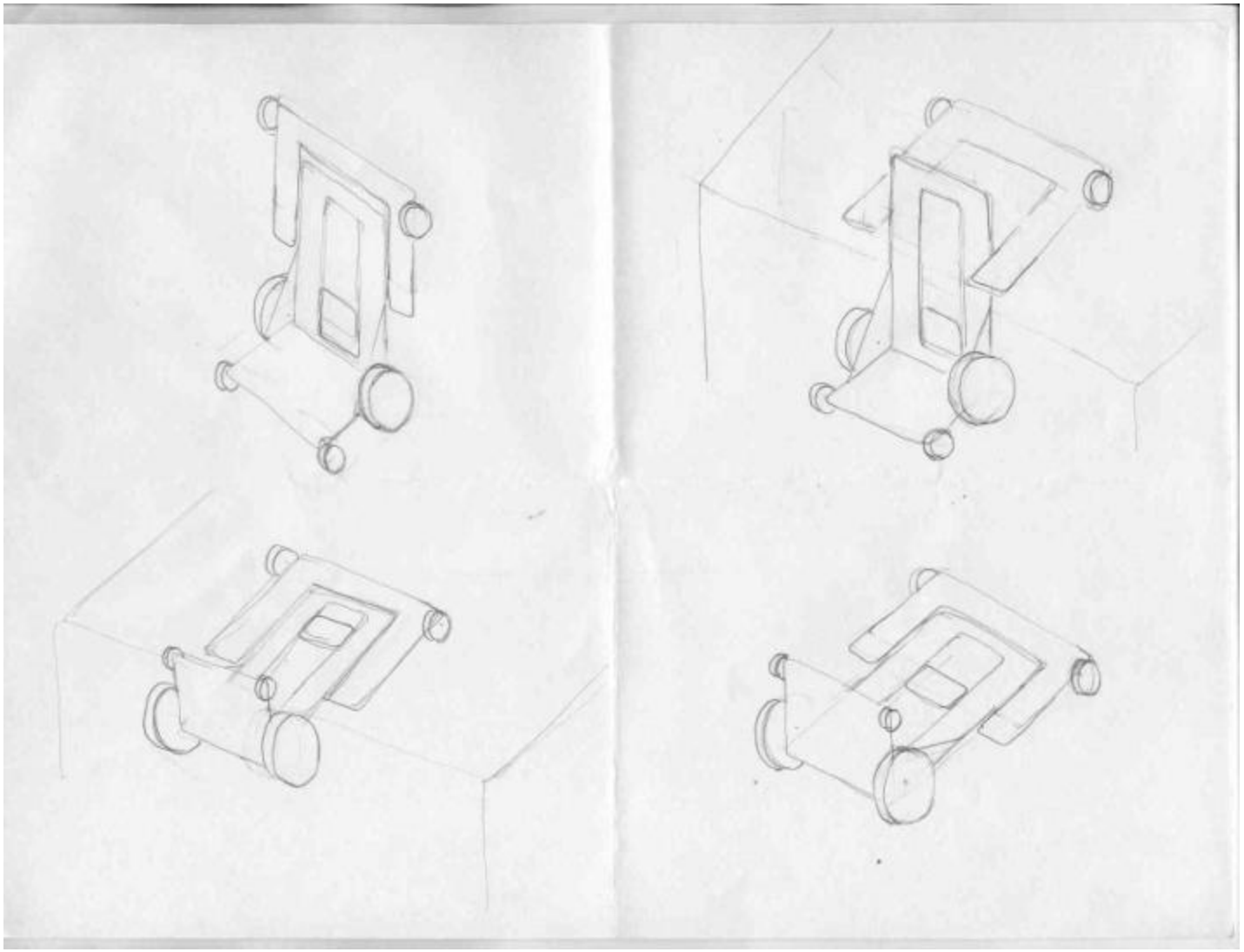


Design alternative #4

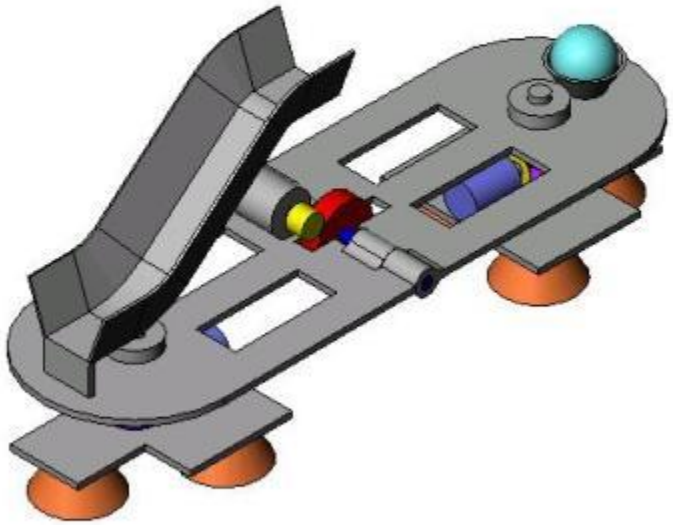


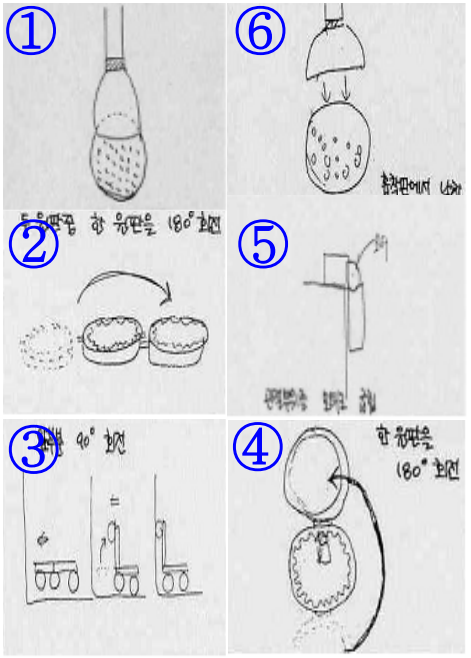


Motion check of the design alternative #4

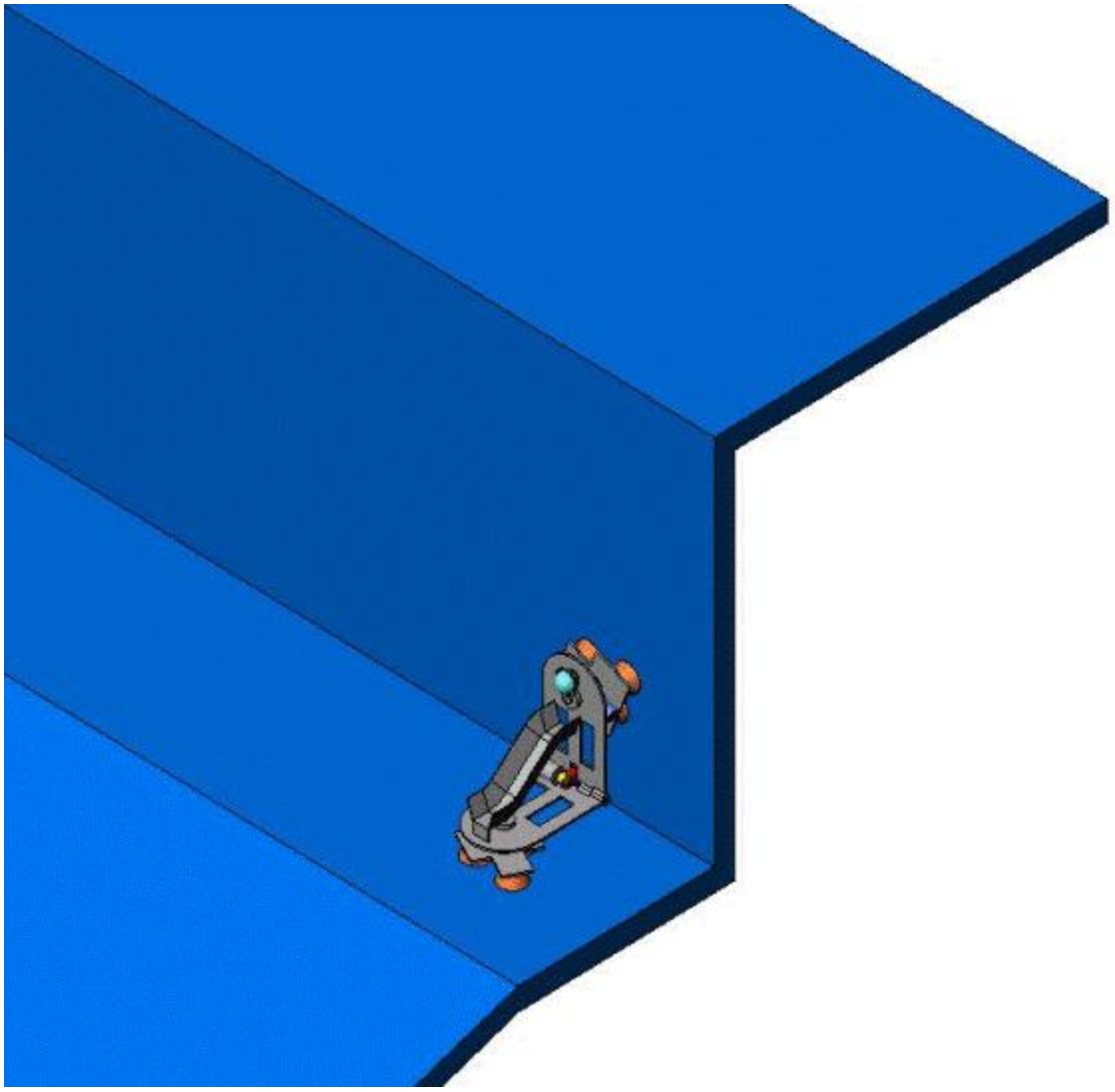


Design alternative #5

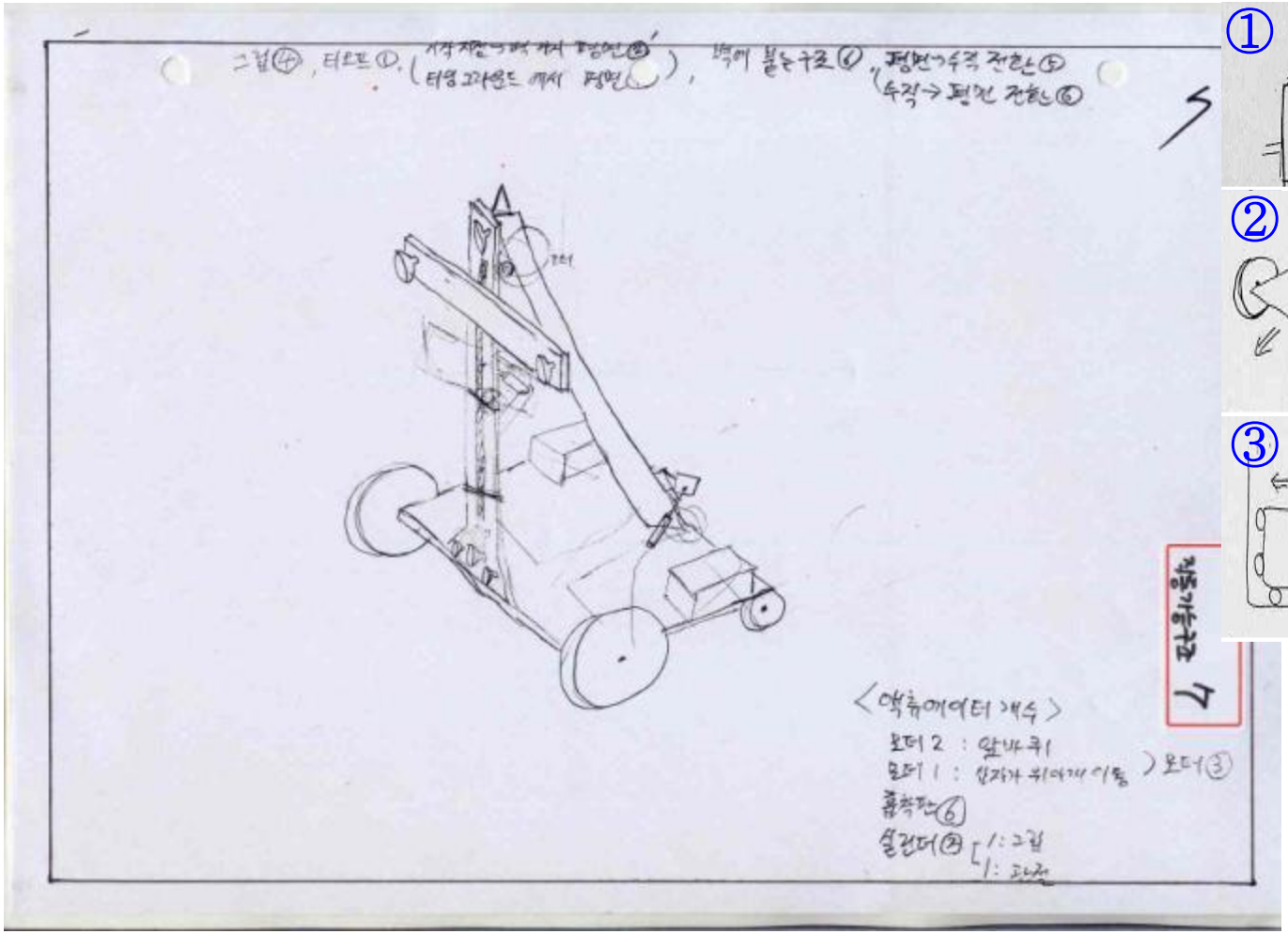


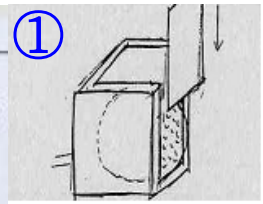


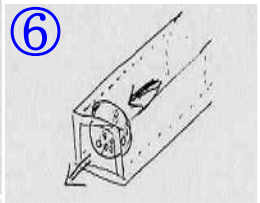
Motion check of the design alternative #5

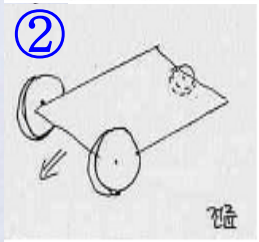


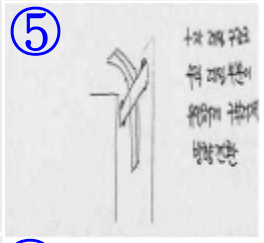
Design alternative #6

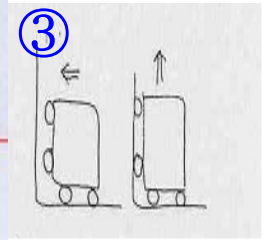


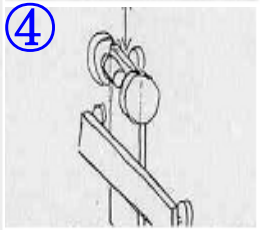




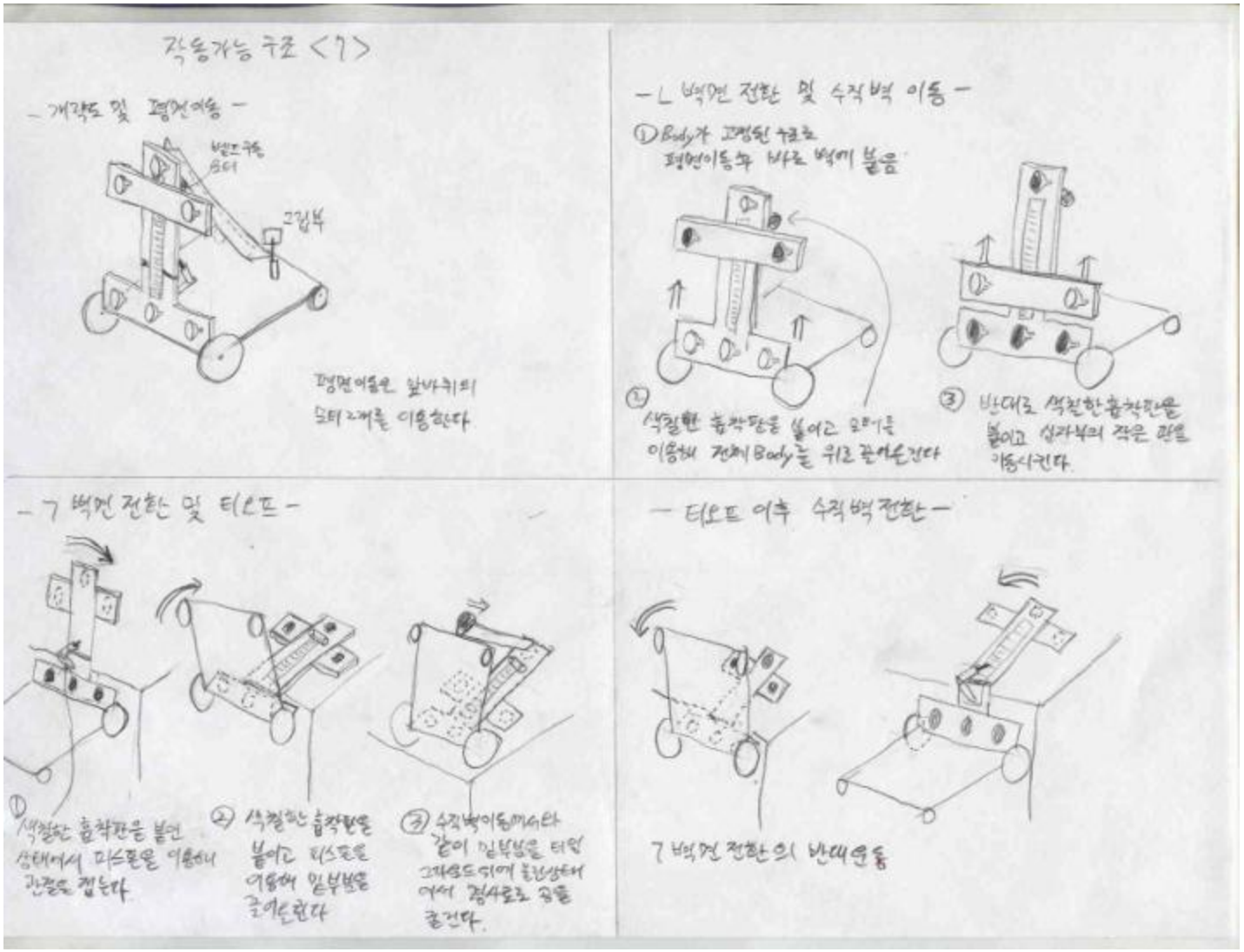




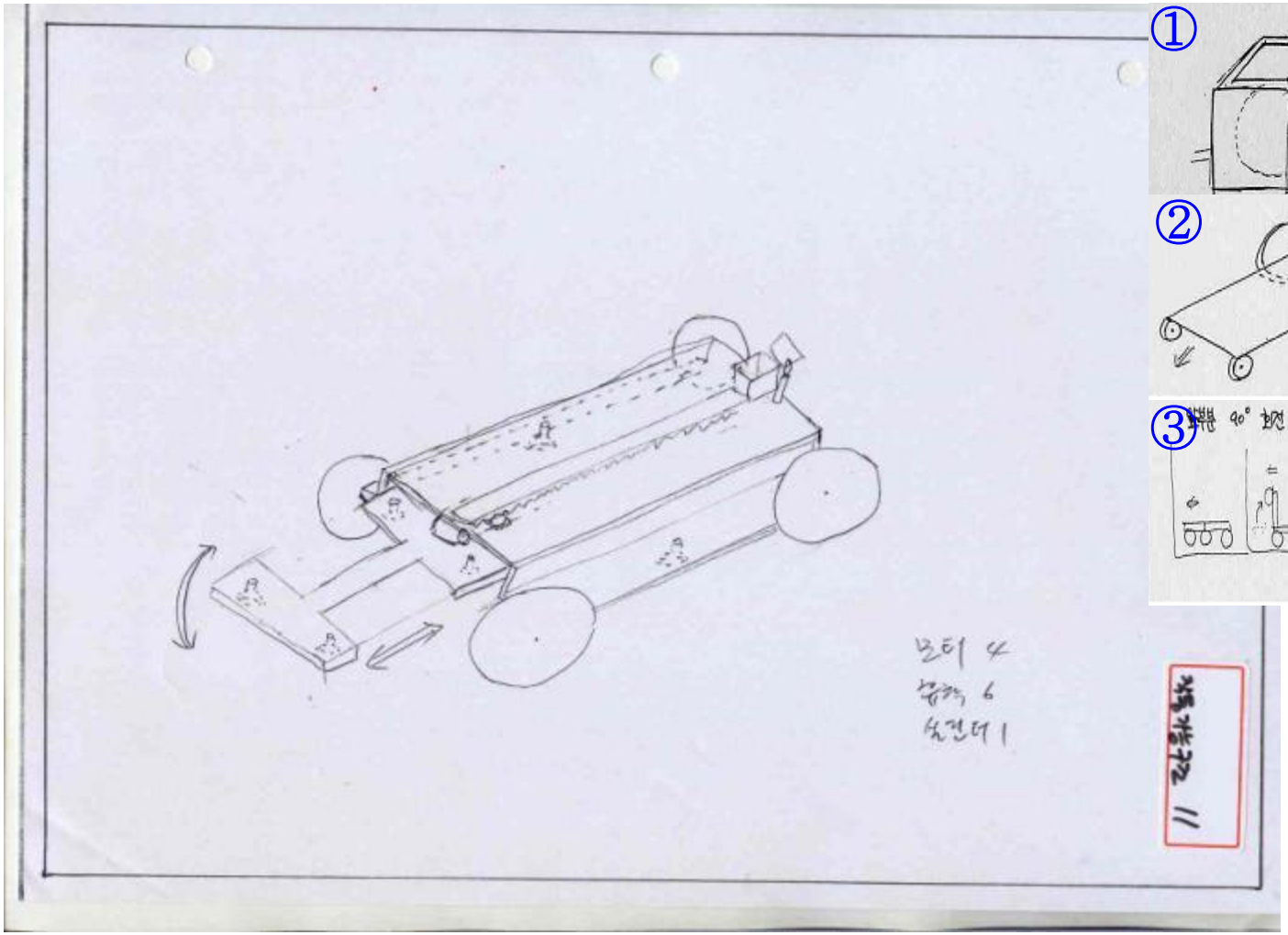


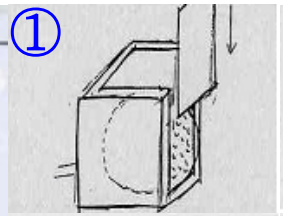


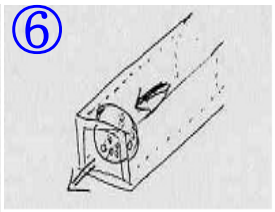
Motion check of the design alternative #6

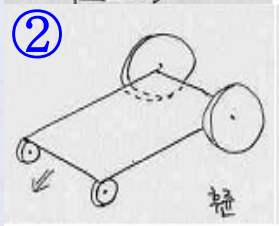


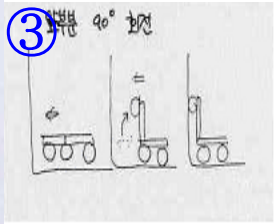
Design alternative #7





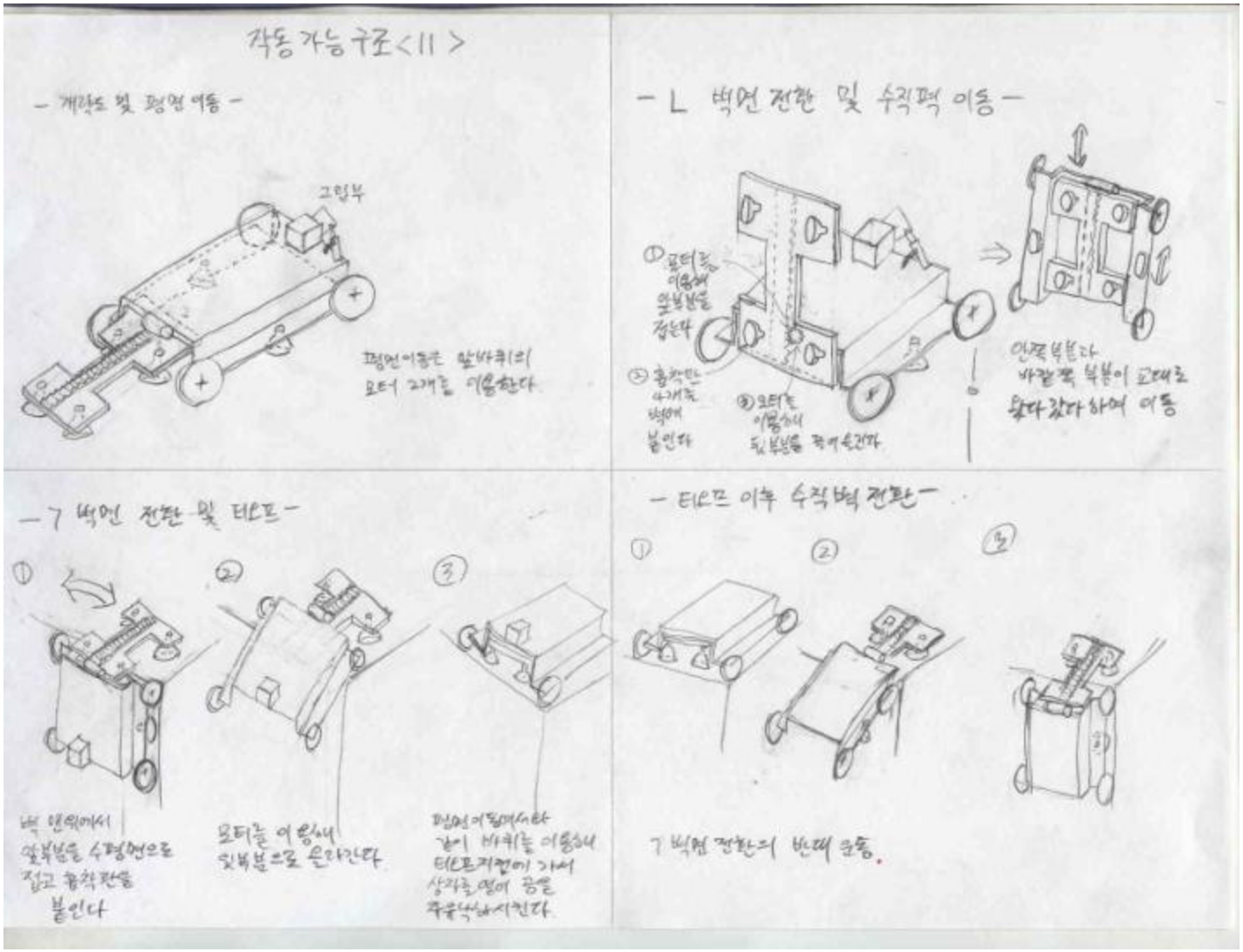




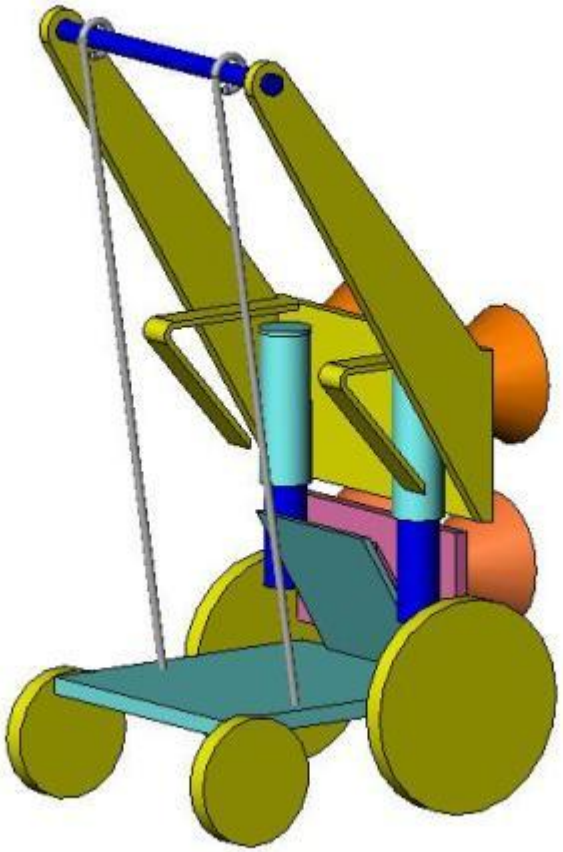


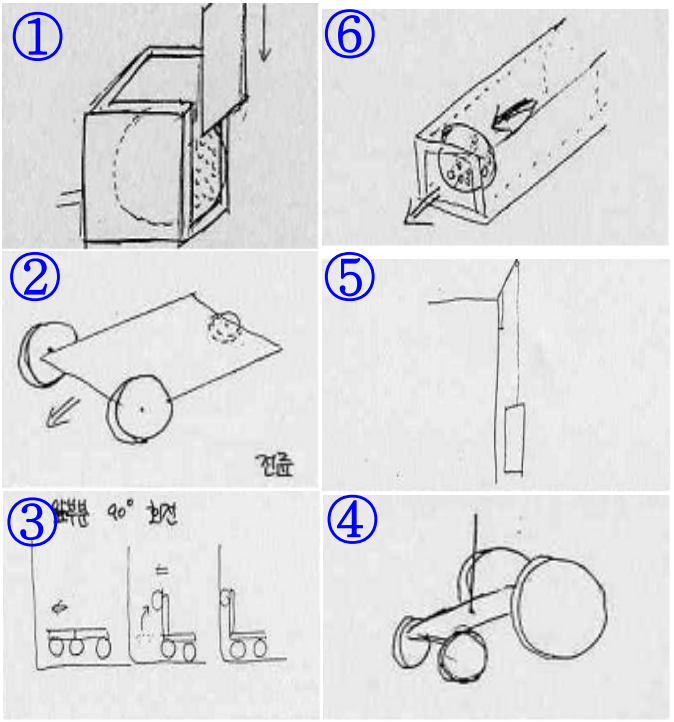
④

Motion check of the design alternative #7

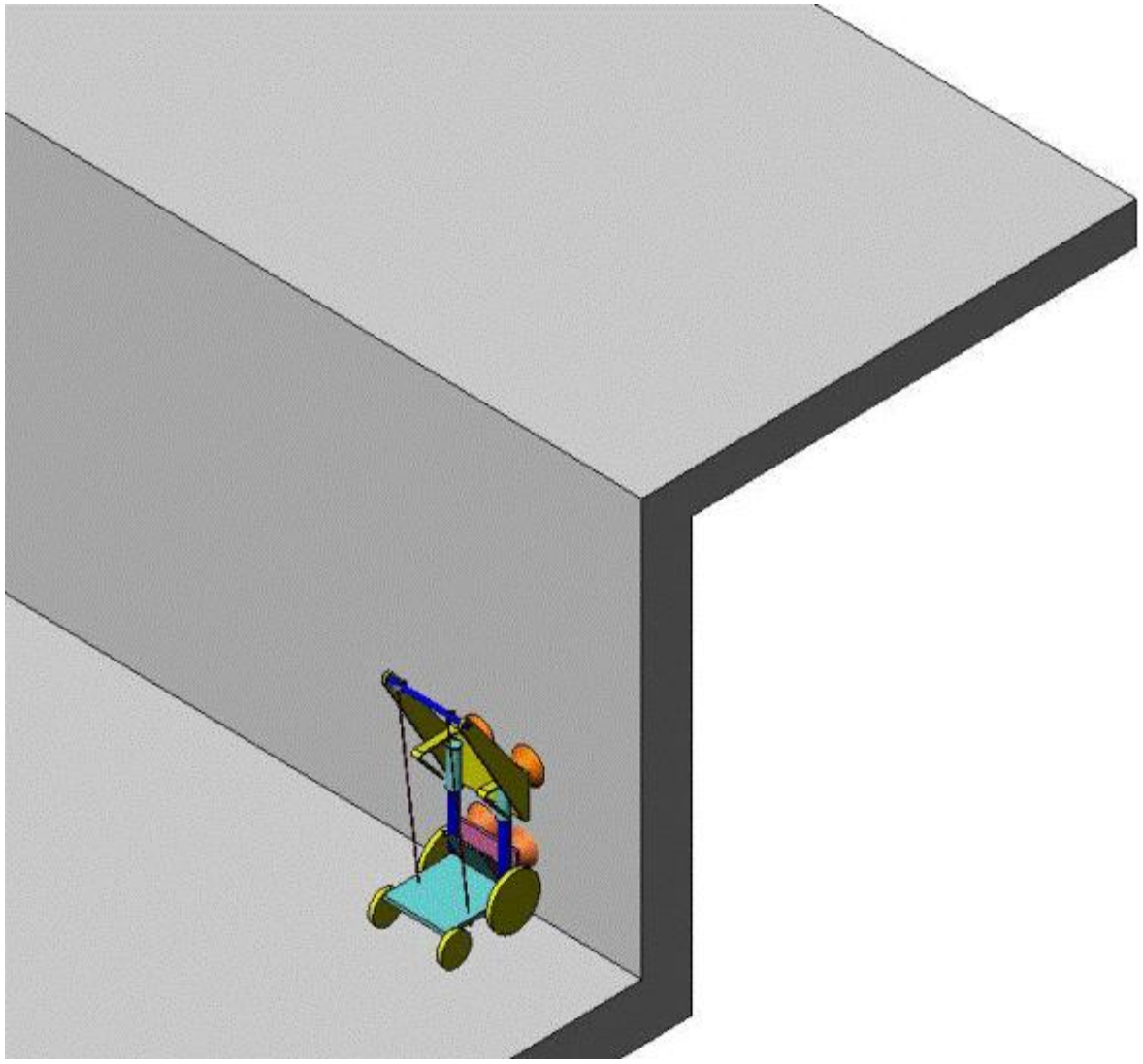


Design alternative #8

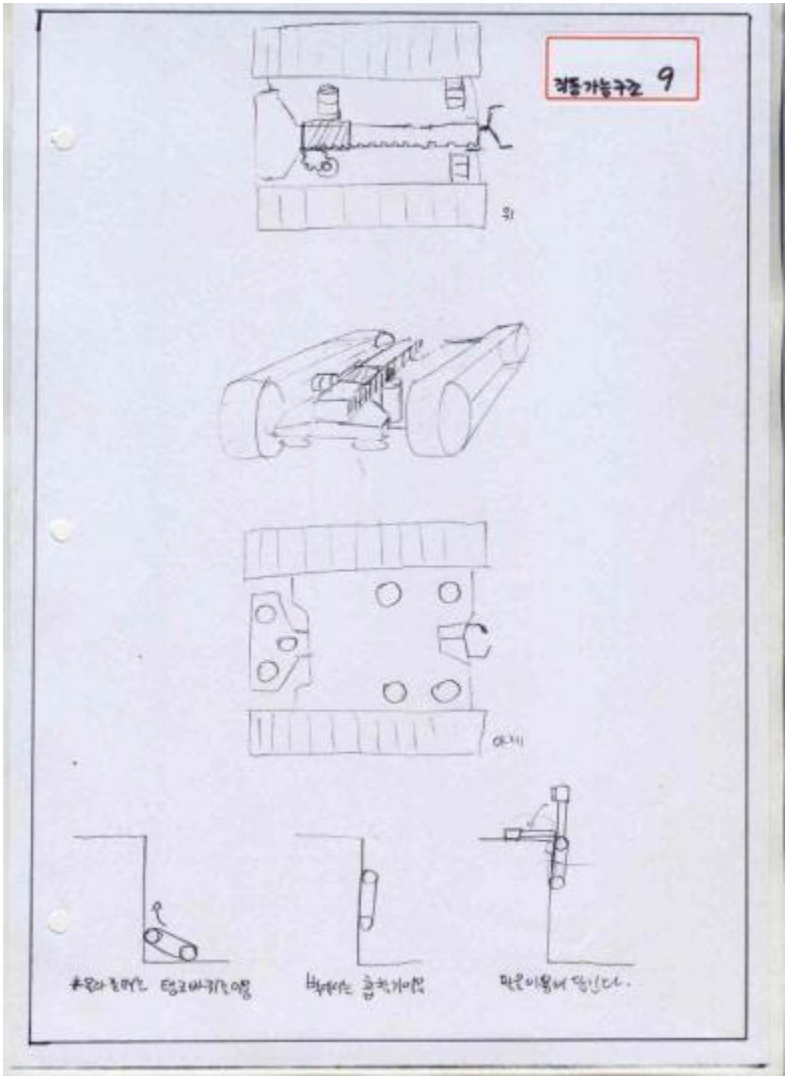


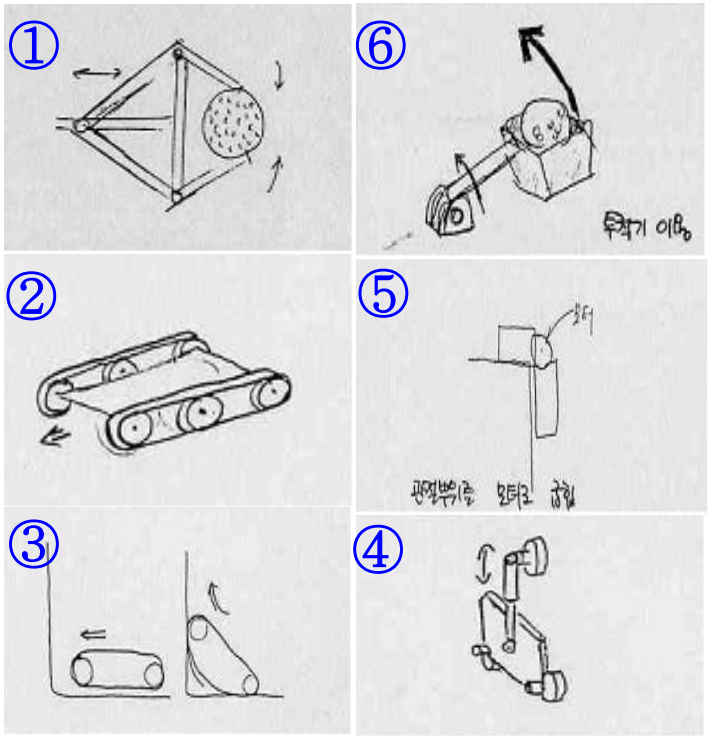


Motion check of the design alternative #8

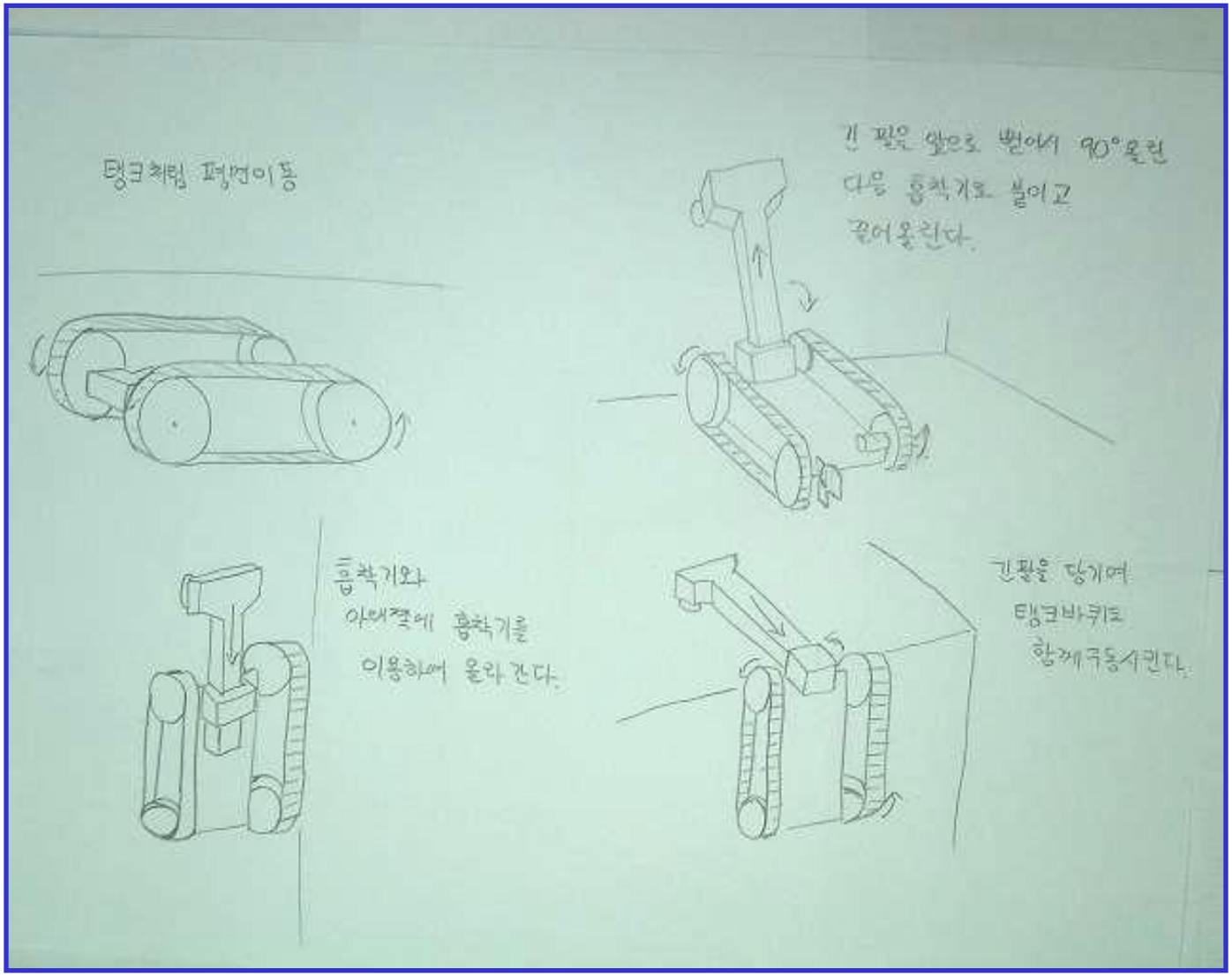


Design alternative #9

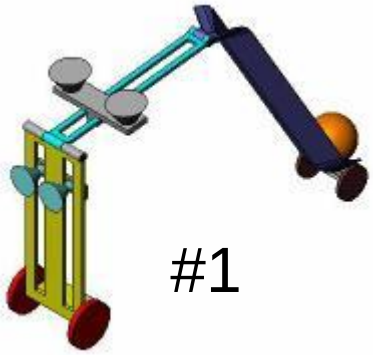


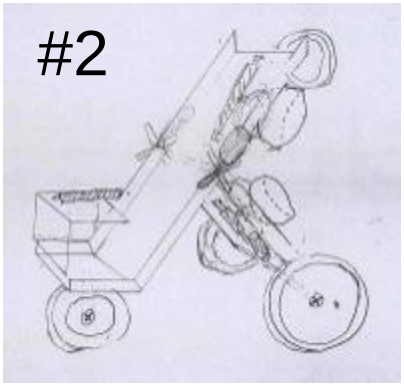


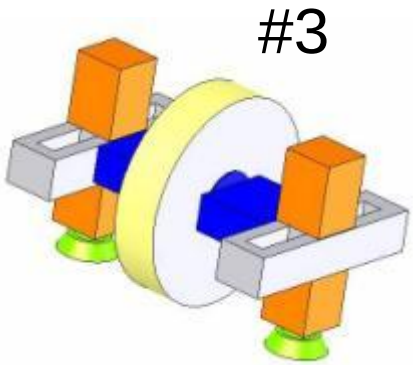
Motion check of the design alternative #9

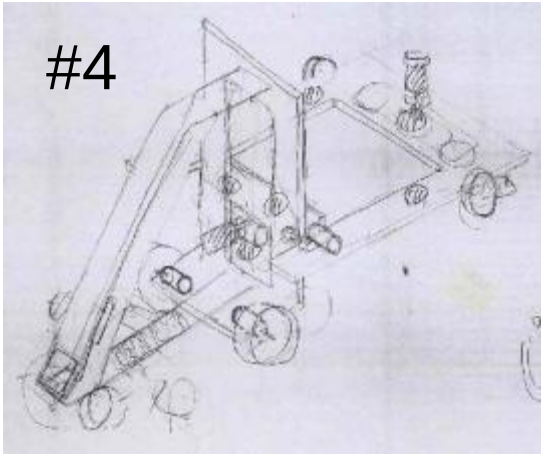


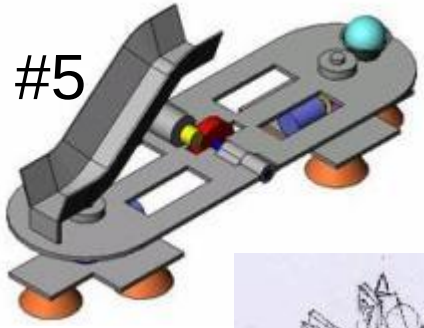
In conclusion, one team created nine design alternatives by the combination method.

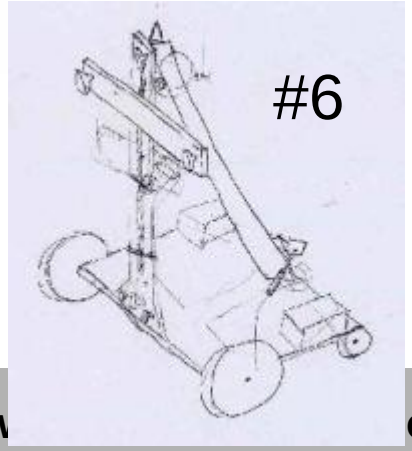


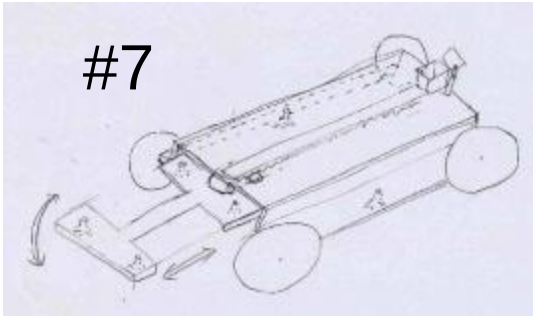


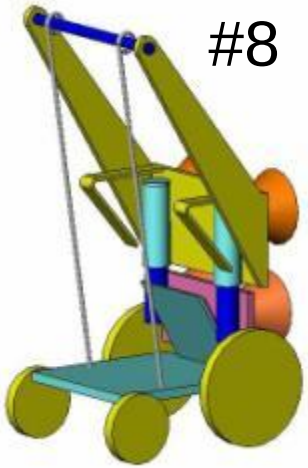


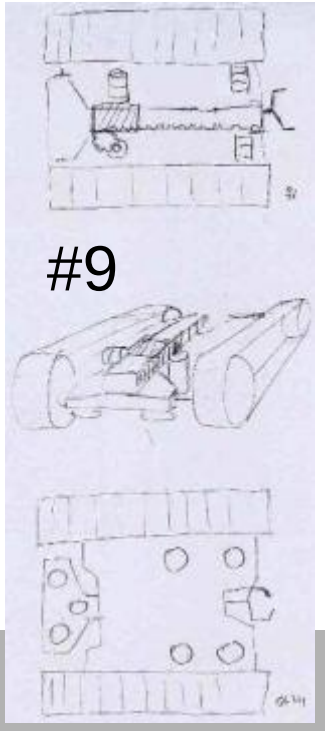








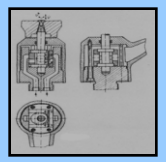
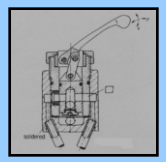
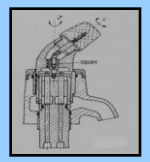
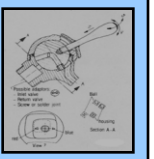




5. Select the final design alternative.

- Discuss the pro and cons of each design alternative
  - Check if each design alternative satisfies each item of the requirements list.
- Try to make an evaluation chart assigning the weighting factor to each items.
- Select one among the design alternatives
  - Or, the final one could be obtained by combining the subsystems from a few design alternatives.

An evaluation chart example: one-hand operated faucet to mix hot and cold water

	criterion			A 	B 	C 	D 
	item	details	weight				
1	function	no leakage	2.0	2	6	6	2
2	robust	less functional variations	2.0	4	6	4	4
3	realize	smaller space	1.0	3	2	2	4
4	simple	number of parts	3.0	3	6	3	9
5	manuf.	machining is simple?	1.0	1	3	2	1
6	ass'y	easy assembly	1.0	2	3	2	2
7	usage	simple manipulation	2.0	2	6	8	4
8	clean	easy cleaning	1.0	4	2	3	2
9	A/S	special tool is required?	1.0	1	3	2	1
sum		total of (weight x grade)		22	37	32	29
		priority		4	1	2	3
conclusion		We select design alternative B. However, we will check for design alternative C if number of parts can be reduced significantly for three weeks, and then will make a final decision.					

Part 3:
An engineer's dream and life

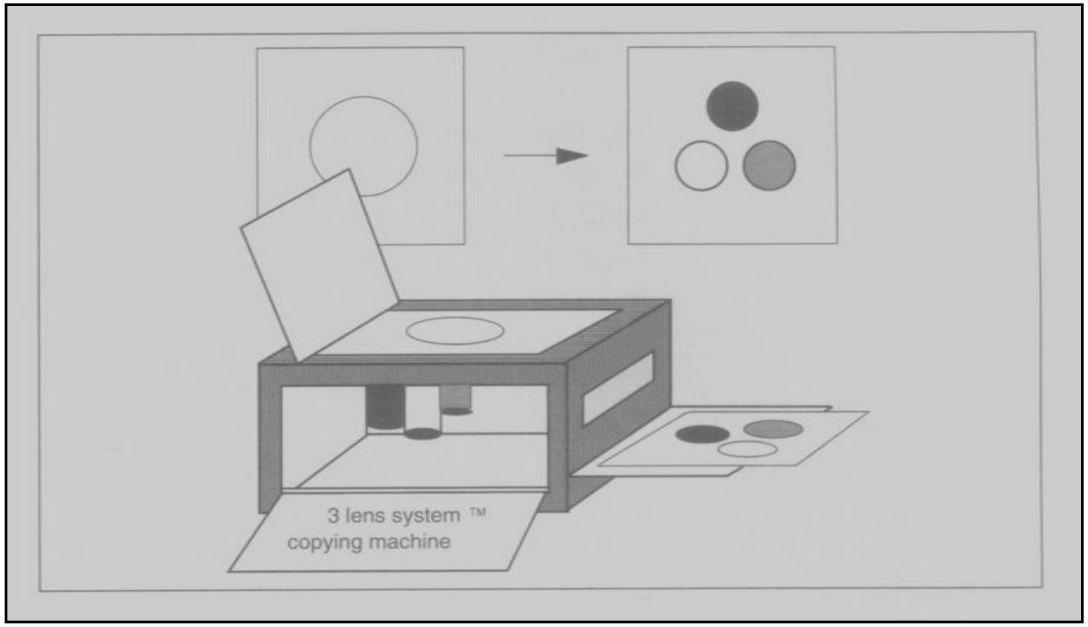
A general copy machine with one lens

- If you repeat the reduction copy

It converges to one spot.

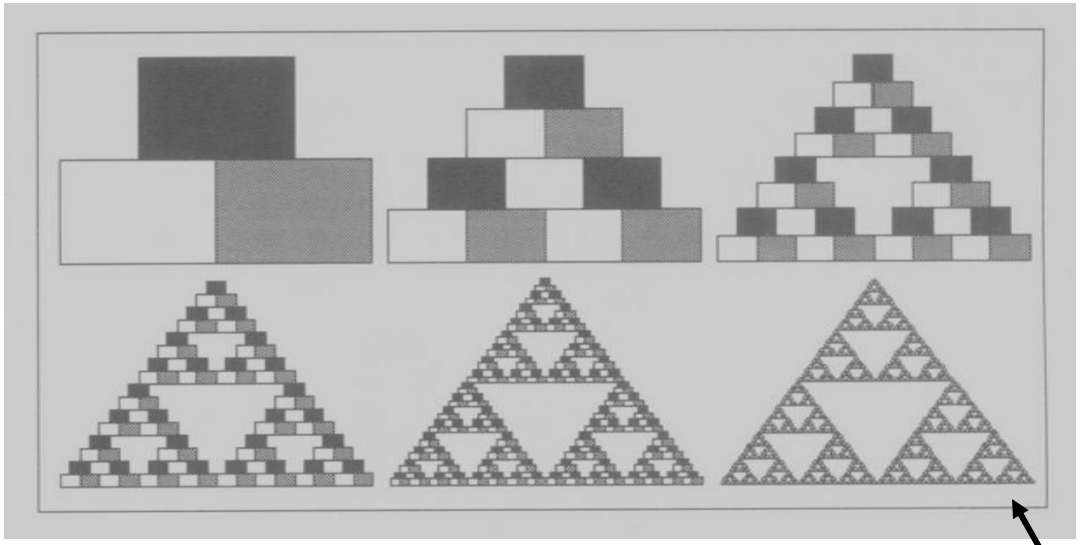
A virtual copy machine with three lenses

- If you repeat the reduction copy



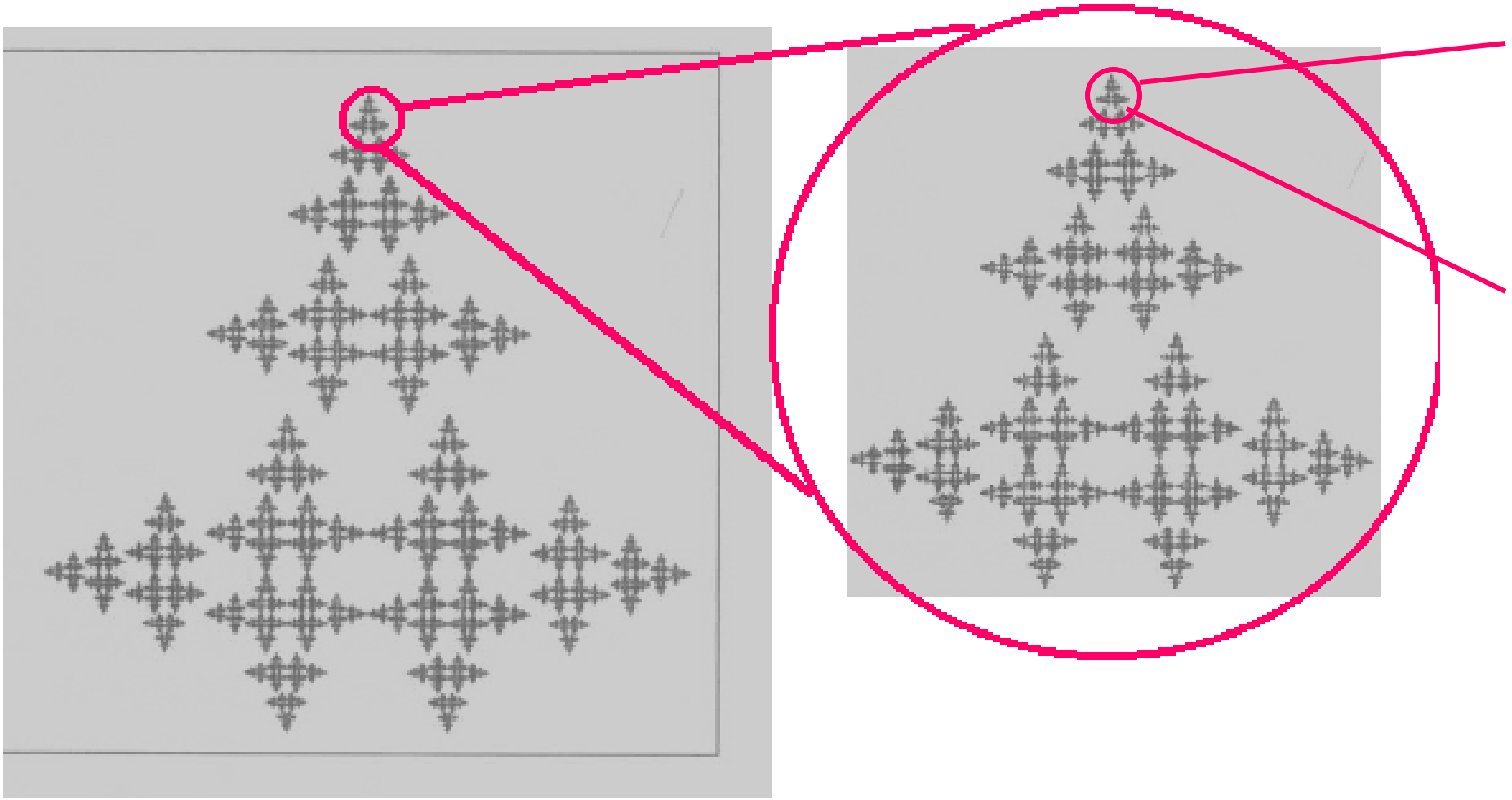
It converges to what?

It converges to a certain fractal image.



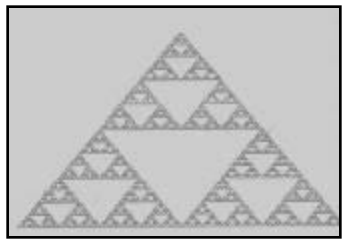
A fractal image

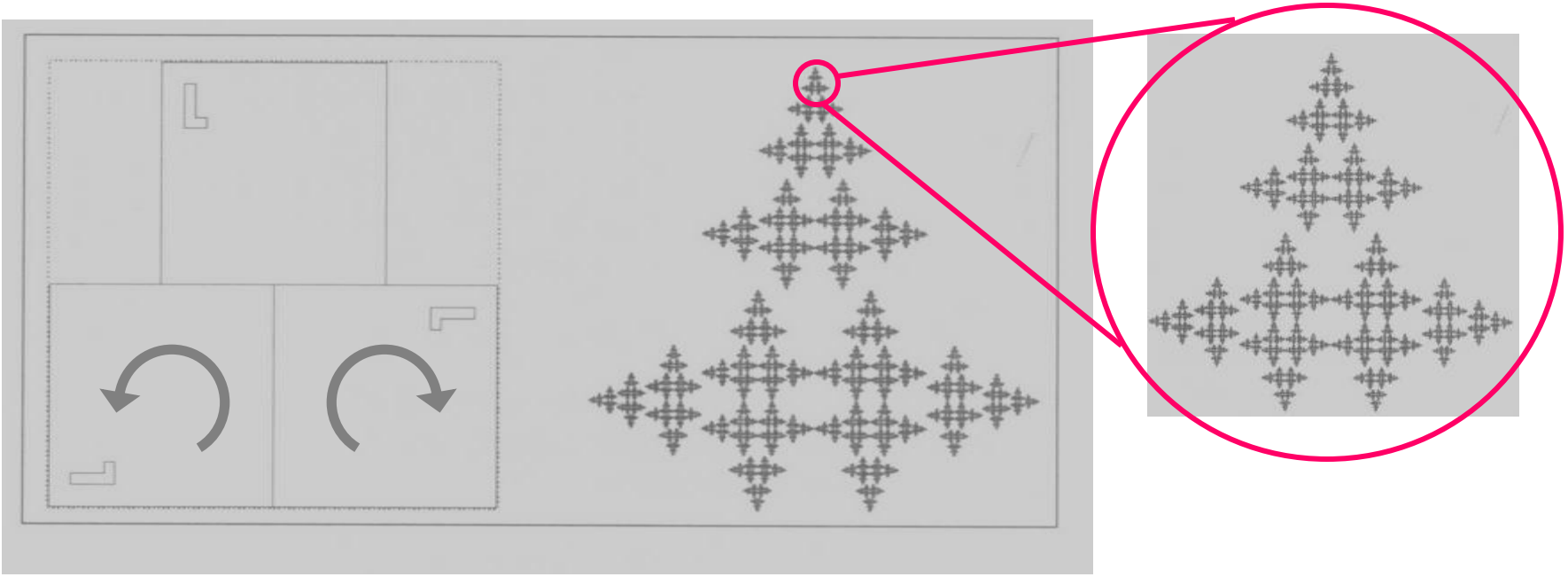
A fractal image on the plane: a part of the whole image contains the whole.



If we change the combination of the lens orientation to 90 degrees…

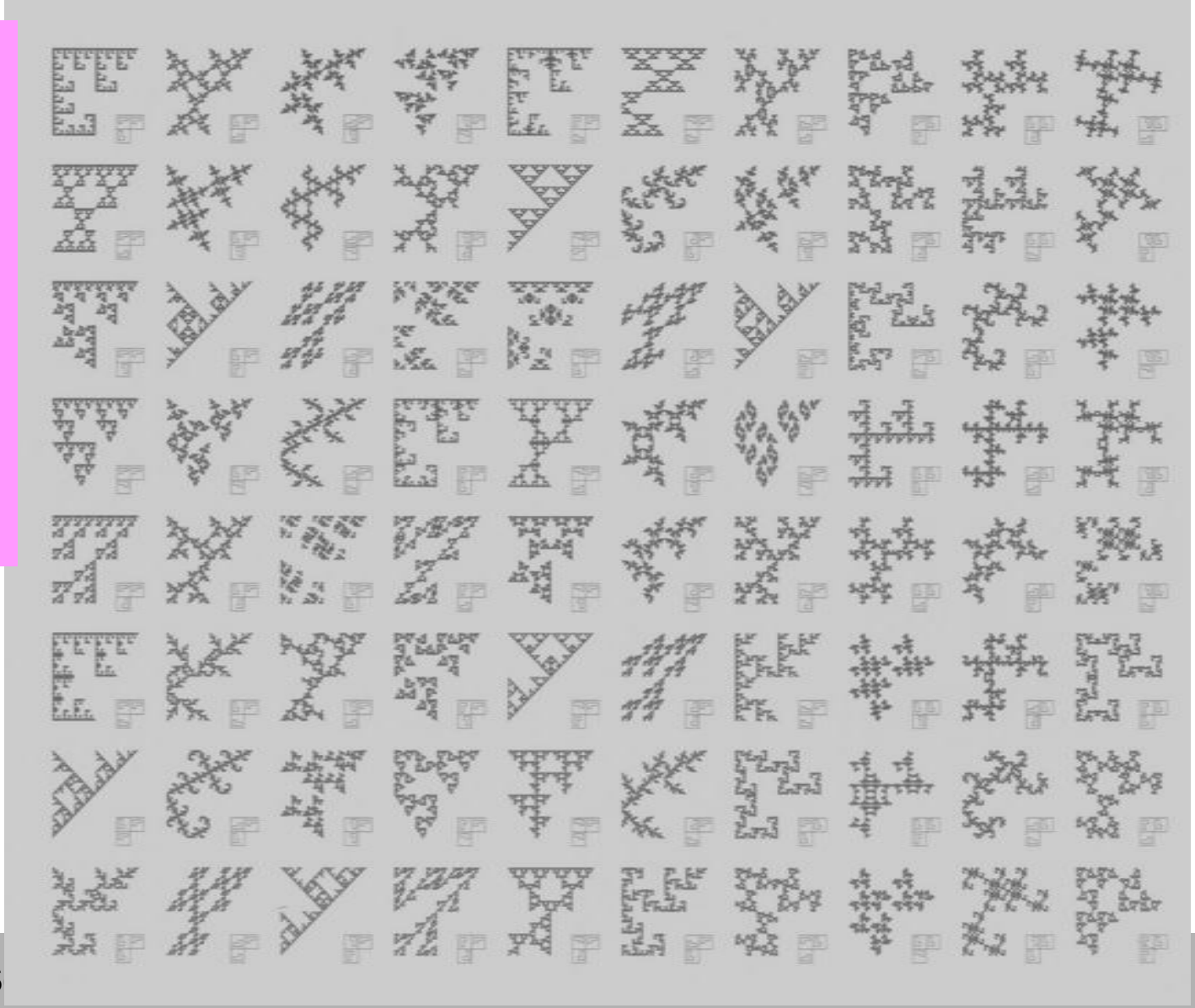
- We get a different fractal image.



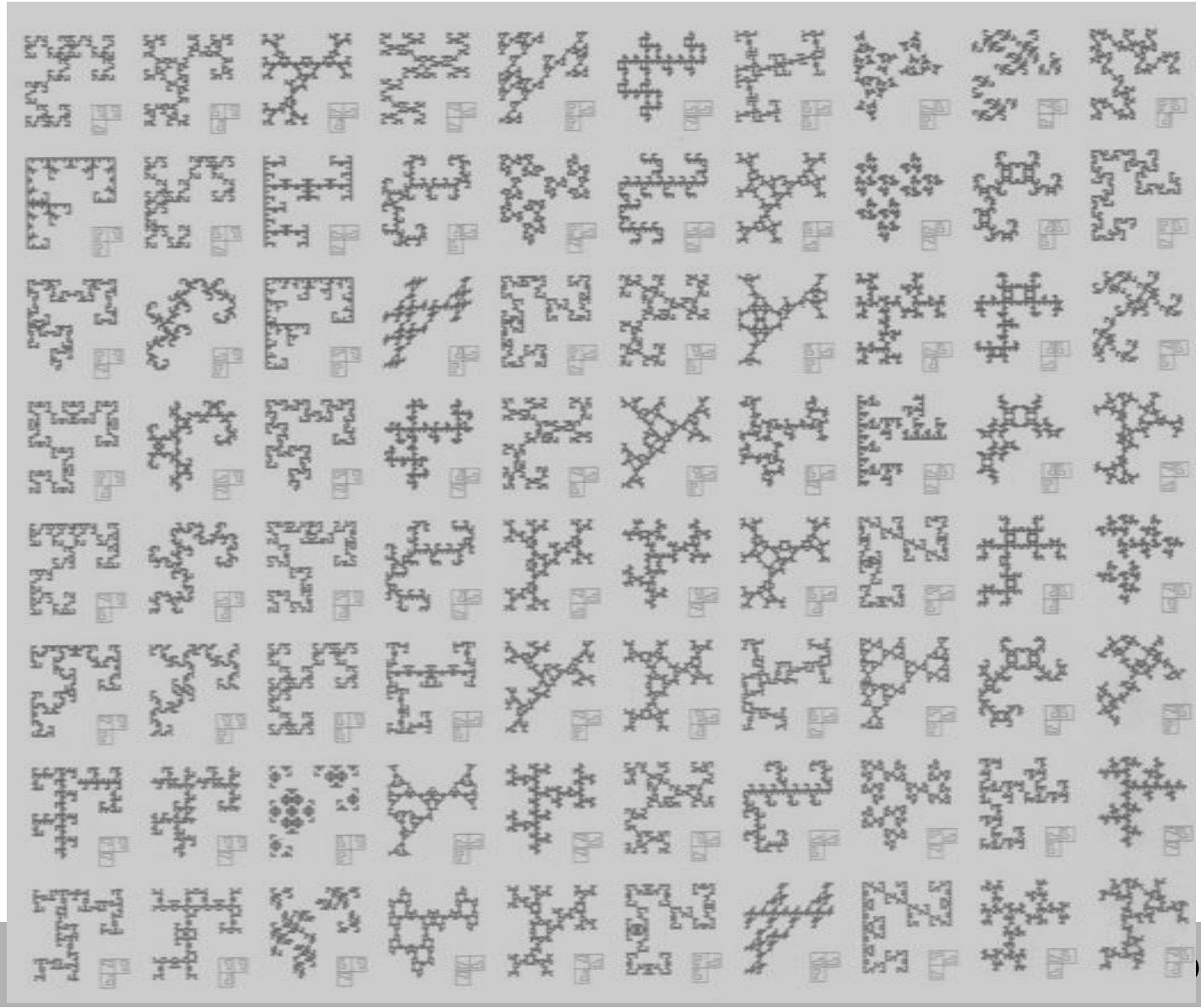


There are so many combination of the lens orientation to 90 degrees (1).

A simple deterministic principle can generate a huge number of various images.



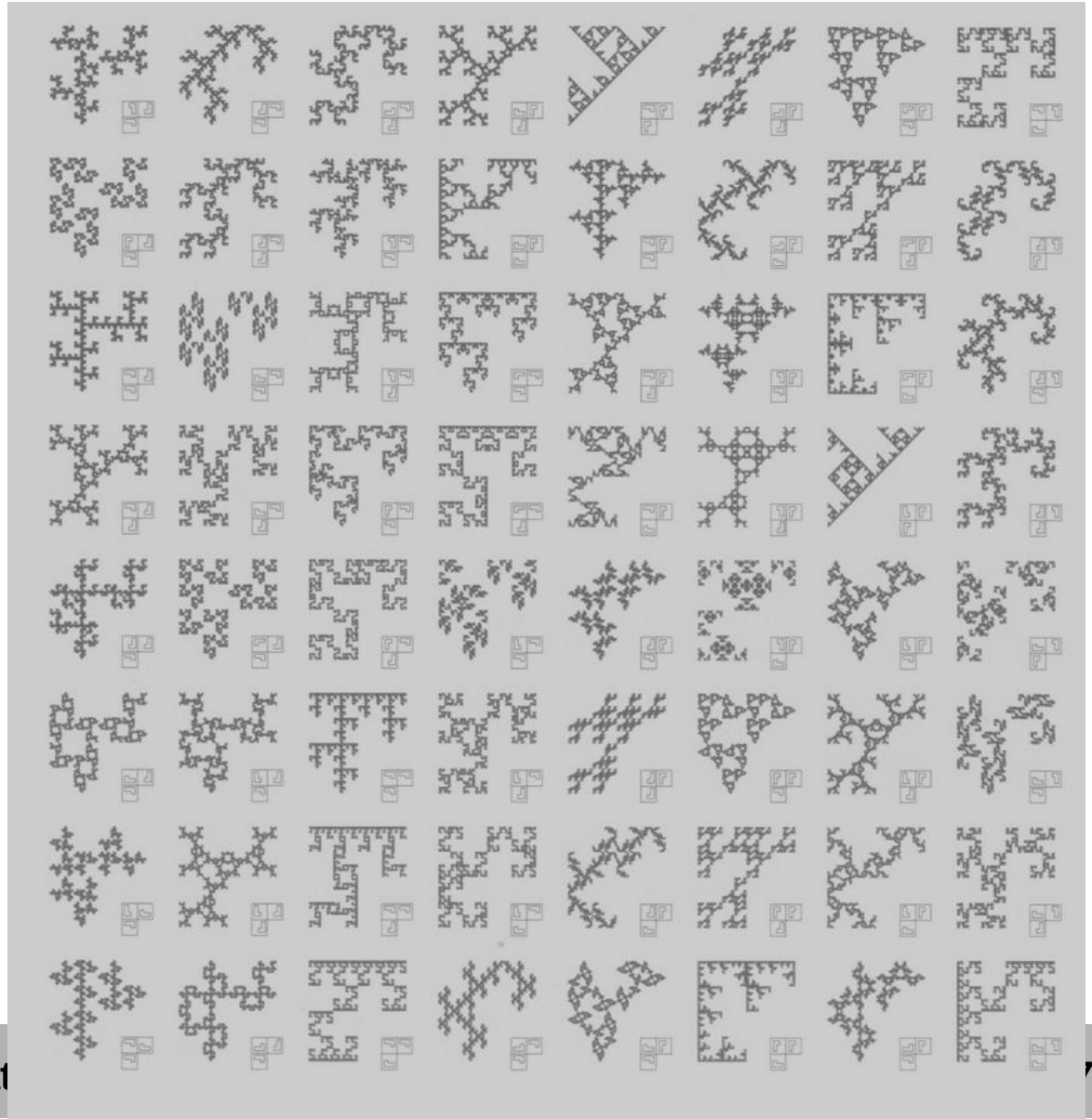
There are so many combination of the lens orientation to 90 degrees (2).



There are so many combination of the lens orientation to 90 degrees (3).

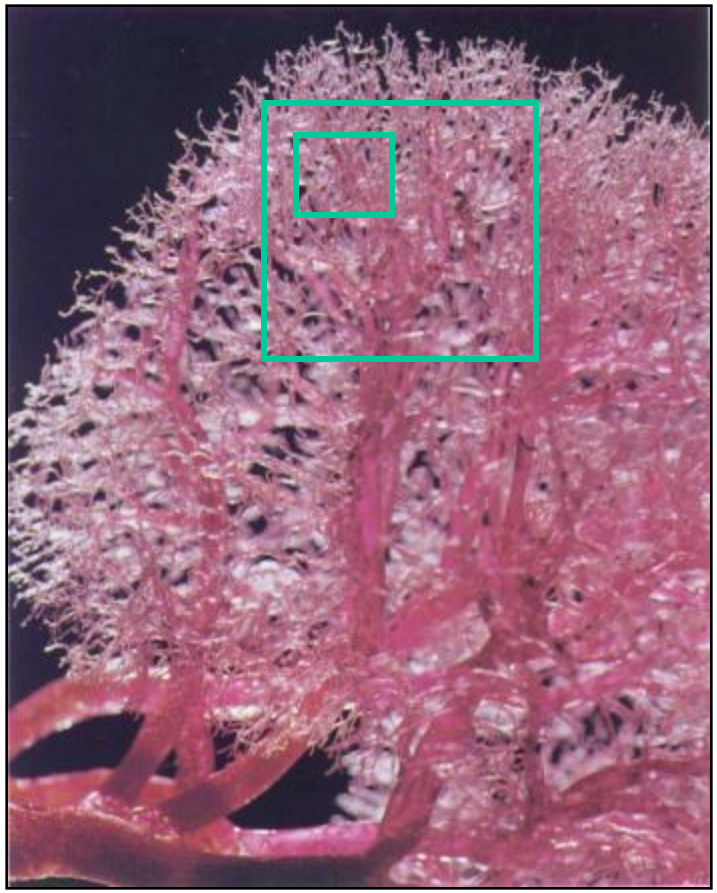
If we change the orientation angle differently from 90 degrees?

If we change the reduction ratio of each three lenses?



There are many fractal image in our world, generated from the simple principle.

A human kidney

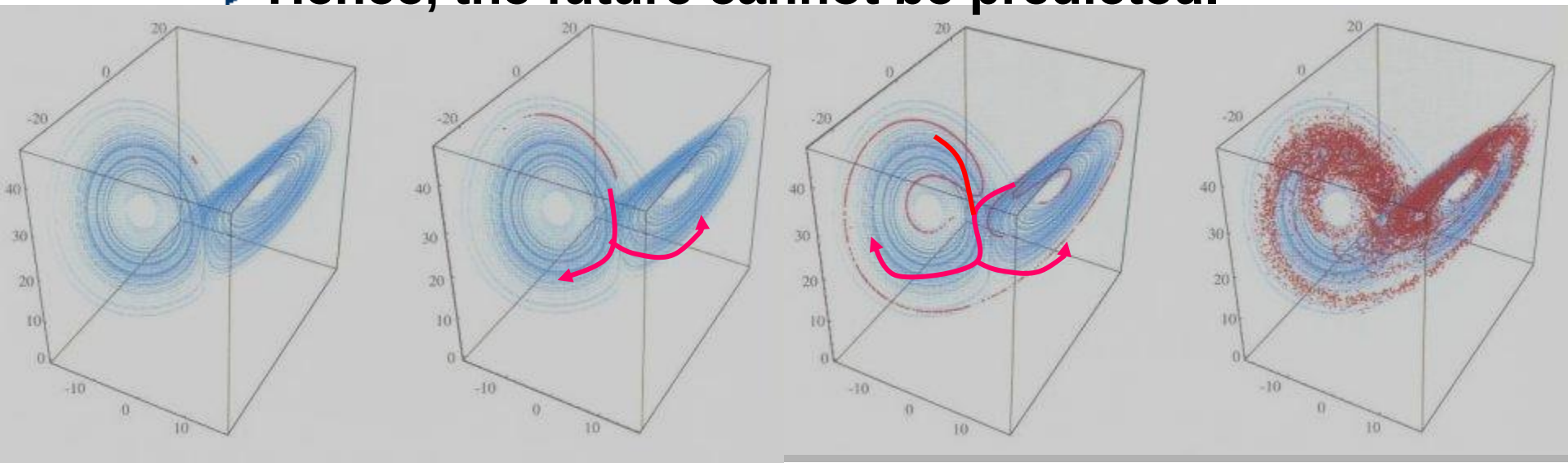


Mountain valley

The fractal images generated by the God's copy machine (?)

If our life is also one of the chaotic nonlinear dynamic systems,

- **Then, our life would has the properties of the nonlinear dynamic system:**
  - **It is very sensitive to the initial conditions.**
    - **The initial condition determines what specific status it will reach in the future among the huge status set.**
    - **Even the two points with very close initial conditions can be located at the extreme different positions with each other.**
  - **Hence, the future cannot be predicted.**



You cannot predict your life, but you need to set up your dream and vision NOW.

- **What is your image after 15 years?**

A government official, a consultant or a lawyer understanding engineering

A professor

Top 1%
Global leader

A CEO of a big business group

A professional researcher

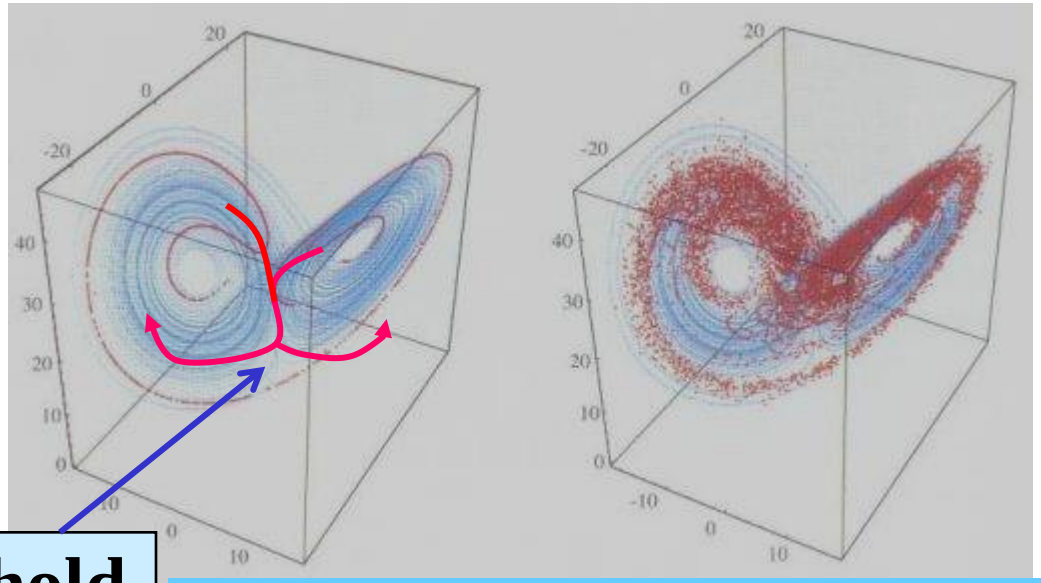
Microsoft

YAHOO!

A founder of a venture business

Why do you need to set up your dream and vision NOW?

- You are encountering small or serious thresholds every moment.
  - Sometimes you do not recognize if it is a threshold or not.

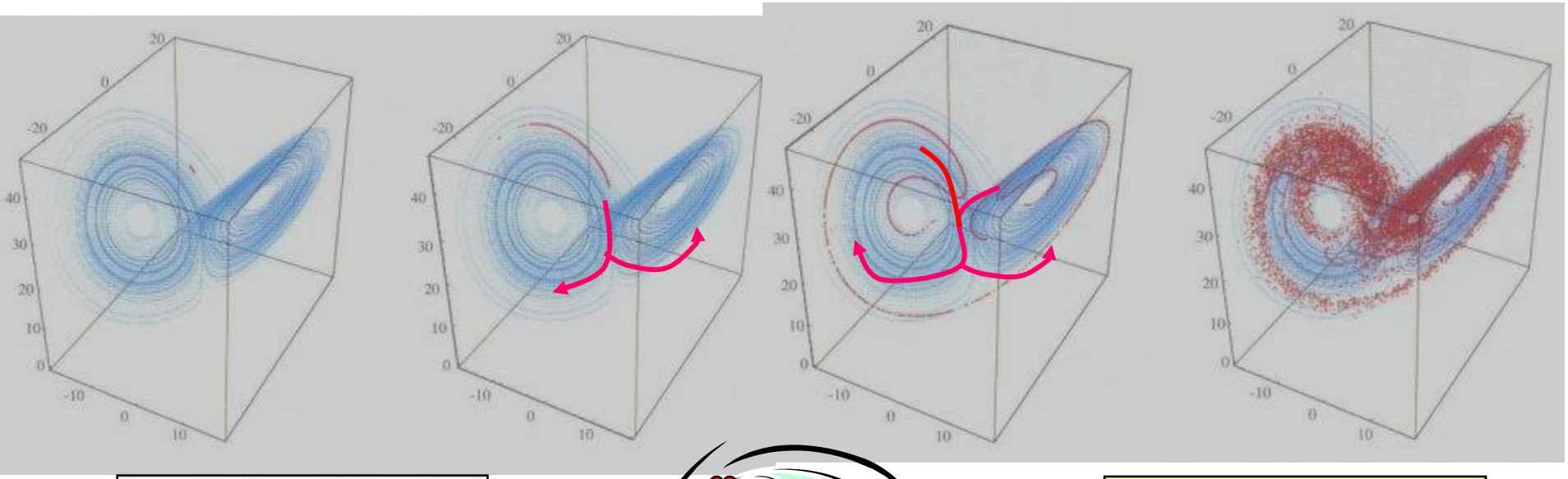


threshold

When you make decision
or you are decided by others.

You never give in at any threshold even if it seems to be trivial,

- once it is related to your dream, since your life is an initial condition game.



Your 20 years

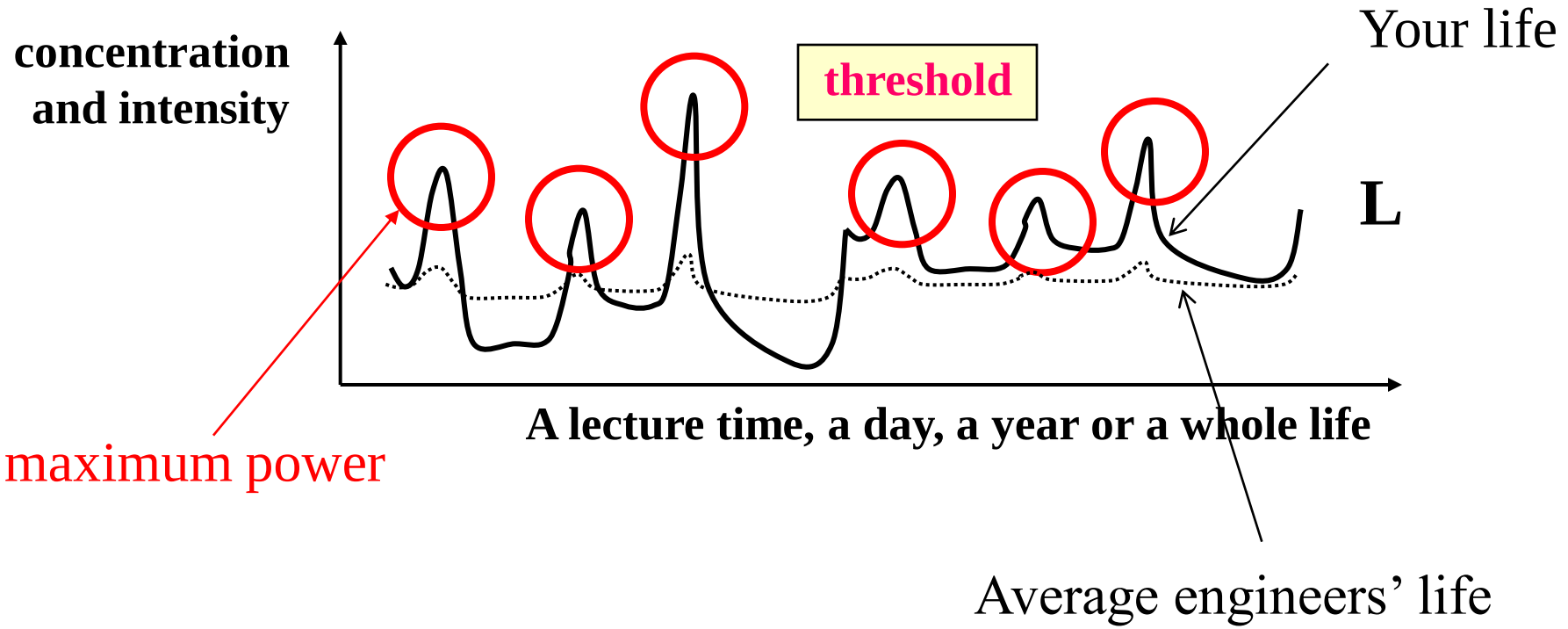
Your 30 years

?

Your 40 years

Only your dream will make you break through every thresholds to come by your maximum power.

You are not going to be the average engineers?



I believe that all of you become top 1% global leaders in the future.

Good luck.