MASTER THESIS

TITLE: Bio-Triz: The combination between Biomimicry and Triz

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Contents

List of Figures

List of Tables

CHAPTER 1

1.1 Problem statement

When you are faced with a Problem, what do you do? Sometimes we solve it without thinking about the effects it may have on the environment. It might be a good way to solve a problem, but it may not be good for a sustaining the environment.

Mankind is inextricably linked with nature. We cannot ignore nature's feedback whenever we attempt to go beyond the limits of nature. As we are now more careful about the relationship between humans and nature, we have to find new methods to solve technical problems while considering the effects on nature. In the future when we are faced with a problem, we need to solve it in a balanced way.

We need become more attentive to our environment when we resolve our problems. Our environment is not only the place we are living in, but it is also our model, measure, and mentor. Therefore, we propose using the theory of biomimicry when we are facing and solving a problem.

1.2 LITERATURE SURVEY OF BIOMIMICRY

Many famous inventions and architecture are based on the theory of biomimicry. In recent years, the theory of Biomimicry has been widely used in many different fields. Why use Biomimicry? How has it been used to solve engineering problems?

We see the consequences of our negative actions on the environment and it makes us feel overwhelmed. We do have to solve these kinds of problems, but we cannot destroy the natural environment. Due to these factors, we have to solve the problem in nature's way. As the founder of Biomimicry, Janine M Benyus says in her book [1]"we have to treat nature as our model, measure and mentor." We can combine nature with our life, and learn from nature, and do things in nature's way.

The Wright Brothers successful flying of an aircraft is a famous example of engineering which would later become known as biomimics [2]. They did not know that they had established the foundation for biomimicry. Similarly, Otto Schmitt, an American academic and inventor, developed the idea of using nature-inspirations. In 1960, Jack Steele said "humans had learned something from nature, and made it into our life." [3] Otto Schmitt and Jack Steele realized that we can learn things from nature, which was biomimicry. However, the term "Biomimicry" was not mentioned until 1982, and later, in 1997, Janine Benyus wrote a book "BIOMIMICRY: INNOVATION INSPIRED BY NATURE," which popularized the term biomimicry.

After Benyus's book, biomimicry was widely spread. The idea for a new motorcycle was learned from a running horse [4], and the idea of using a nest as inspiration for a national stadium was learned from a bird's nest. These are examples of using the biomimicry[5] technique to create new things. Inventors used the principle of biomimicry to invent things just like nature did.

In the present study, biomimicry is the best way to make contribution to the place where we are living. Also, biomimicry will have an effect on our life in the future. Not only will it affect engineering, but also business, art, architecture, and other industries.

1.3 OBJECTIVES

The thesis has three objectives. The first objective is to use the approach of biomimicry to solve engineering problems. Secondly, it is to use the method of TRIZ to solve problems. Lastly, it is to combine biomimicry and TRIZ to solve both engineering problems and problems in other fields.

1.4 SUMMARY OF BIOMIMICRY

This discipline is about how humans can learn things from nature and use this knowledge to solve difficult problems. In the Benyus book we learn "how to echo nature, how to feed ourselves, how to harness energy, how to make things". Moreover, it also states "how to heal ourselves, how will we store what we learn, how we conduct business, and how we go from here". These are prompts to cause us to study inspirations we can get from nature.

Why biomimicry now? What can we do to echo nature? These two questions were asked here. The author sees that we can get useful resources from nature, but we may destroy the balance between mankind and nature. We have to know how to live and sustain the earth. This goal is not only for humans, but also for our homeland. As engineers realize that, we began to learn many things from nature. Though no one had branded it as biomimicry, it has been in practice for a long time. When Benyus met men and women who were exploring nature's masterpiece, she called their quest biomimicry. This is a revolution, but not an industrial revolution. This kind of revolution is focused on what we can learn from nature, not focused on what we can extract from nature. The more we know biomimicry, the more we can find out that what we should do is just follow nature. This is a combination between biology and mimicry, as nature becomes our instructor as we go further.

There are many different approaches for humans to feed themselves in different places. In Japan, some of them run a system that they call "do nothing", which needs no labor on his behalf. This does not mean a lack of labor, but the avoidance of manufactured inputs and equipment. This kind of farming can also be described as ecological farming and is related to fertility organic farming but should be distinguished from biodynamic agriculture [6]. Farming in different places are not the same, because it is dependent on different environment. Most of them learned how to grow things from what nature did. "Farming in nature's image" is the most radical and also the most important way for us to think.

Human and animals need energy for sustained life. Therefore, we need energy providers to supply us with energy. Here we find out the way plants transfer energy and harness energy. There are many scientists doing research on harnessing energy and on energy transfer. There are many examples that show how we use the plants to solve our energy problem. For example, in many parts of the world, people get warm water for their homes from systems in which sunshine heats up water inside a glass tube or black tank.[7] And this is also the way some plants harness and transfer energy. Mimicry of harnessing energy from plants will influence the way we handle our energy problems in the future.

The author went to the Material Research Society meeting, and learned 4 tricks from biomimics which were obtained from nature. While we are making new inventions we have to follow the 4 tricks (which are Life-friendly manufacturing processes; An ordered hierarchy of structures; Self-assembly and Templating of crystals with proteins), which can keep us on the right track and always under natures' limits. If we do, we will be able balance to human's and nature's existence. Furthermore, it is a good way to help us to solve our problem.

Nature is the supreme chemist. Different animals, such as insects are quite intelligent. They have the ability to choose food which is ideal for them just as we do. This is called smart eating. What is more, some animals can even medicate themselves. They are able to find plants to heal themselves. Biologists observe how animals cure their illnesses. If successful, they experiment and analyze if it is beneficial for humans. It is through the animals that we can trap the enormous potential of plant chemicals. Animals experiment with chemicals in plants to find which are good and which are bad by smelling and observing the plants, but we should know the relationship between the animal and the plants. With this knowledge, we can experiment ourselves.

There are lots of ways for us to record what we learned. The nerve cells are the storage space for information. Now, more and more techniques are appearing for us to use as knowledge storage. For instance, computers use silicon to store things, jigsaw computing is learn from nature using three-dimensional functions by dividing computer into three functions which are assemble thyself, survival of the fittest code and giving up control. No matter how we store what we learned, the functions between our brain and computer are similar, but the ways are very different. There are some ways to show that a computer is not a brain, as a brain can work and learn at same time; secondly, brains are unpredictable; unlike computer brains are not structurally program like computers are. In addition, brains compute physically. With further development, jigsaw computing use silicon computing in a carbon key, quantum leaps, and even DNA will help us store what we need. There must be better ways to help us store what we learn in the future.

Traditionally, we conduct our business in a way which may not be so sustainable. A huge amount of pollution is produced. How long can we use the resource? What will the environment become?

Our realization of these problems is a signal that we want new and innovative ways to conduct business. If our desires are green, we have to conduct business under nature's direction, and we cannot push nature's limit. For example, three types of systems are introduced for us to emulate nature's economy.

1. Type one is the opportunist; Examples are the weeds in a farmer's newly turned field, the bacteria in a tupperware of leftovers, or mice in a cat-less barn.

2. Type two consists of perennials; Examples are berry bushes and woody seedlings that move into the field.

3. Type three is the type will inherit the site and remain dominant until the next big disturbance.

Also, ten organisms in a mature ecosystem are mentioned for us to solve the problems we are meeting now. We can follow these instructions. We need to start conducting business in a sustainable way. It is not only good for us to live on this planet, but also good for the environment's well-being.

As E.O.WZSON, author of *Biophilia* and *The Conservation Ethic* said "Humanity needs a vision of an expanding and unending future." We have to go further to understand nature. There will be four steps to a biomimic's future.

1. Quieting : Immune ourselves in nature,

2. Listening : Interview the flora and fauna of our own plant,

3. Echoing: Using nature as a model and measure,

4. Stewarding: Preserve life's diversity and genius.

The book tells us how we can find out new ways to combine nature with our ordinary life. We have to use different ways of thinking about nature in order to solve life's problems. As a result, we know the way nature feeds itself, to do what nature wants to serve nature itself by using different methods. All of these methods of nature will be the biomimicry principles for us to follow when we want to learn something which is useful to us and can help us solve problem in nature's way.

Chapter 2

INTRODUCTION AND LITERATURE REVIEW OF TRIZ

2.1 PROBLEM STATEMENT

In many fields, there are problems that need to be solved. Especially when we are facing a problem, and we have no idea in which way we can solve the problem, we have to set up several contradictions of the problem and we need to use the contradiction to find out the principle to solve it. At this time the principle of TRIZ will be used as a tool to help us set up and solve problems.

2.2 LITERATURE SURVEY OF TRIZ

TRIZ was developed by the Soviet inventor Genrich Altshuller and his associates. It was started in 1946 when Altshuller was working in the "Inventions Inspection" department of the Soviet Navy. During the war, he realized that when we were faced with a problem, we might require an inventive solution if there were some contradictions we could not solve which he called "technical contradictions".

In 1950, Altshuller was arrested for political reasons [8] and sentenced to 25 years in the Gulag, interrupting his TRIZ work. Until 1953, following the death of Stalin, Altshuller was freed and returned to Baku. Three years later, came the first publication of TRIZ titled "On the psychology of inventive creation" which was published in "Issues in Psychology" journal [9]. In 1969, after reviewing about 40,000 patent abstracts, he developed the concept of technical contradictions, the contradiction matrix, and the 40 principles of invention. One year later, he developed the concepts of physical contradictions"[10]. Also, there were numerous other theoretical and practical approaches developed by Alsthuller.

The first TRIZ teaching facility, called the Azerbaijan Public Institute, and the first TRIZ lab was set up for invention creation in the year 1971. In 1989, the TRIZ association was established, and Althshuller was chosen as the president. After the research was introduced to other countries, it drew attention overseas. Boston established the first study of TRIZ in the USA in 1995. [11]

2.3 OBJECTIVES

For this chapter, there are two objectives. First, we need know the basic principle of TRIZ and know some easy examples. Second, we have to know how to use the principles of TRIZ to set up problems.

2.4 SUMMARY OF TRIZ

TRIZ uses a scientific approach to analyze different kinds of problems that require innovative solutions. The earliest of the research on the theory was based on the majority of problems which require inventive solutions to overcome two contradiction elements. The purpose of TRIZ's analysis is to apply the strategies and tools to set up the contradictions then use appropriate inventive principles as a way to solve the problem.

One of the analytical tools was the 40 inventive principles, which could provide truly inventive solutions. Before using the 40 inventive principles, we have to find out the contradictions of the problem using 39 standard engineering parameters to find out which principle can be used to solve the problem.

The following are 39 Engineering Parameters:

1. Weight of moving object	21.Power
2. Weight of non-moving object	22.Waste of energy
3. Length of moving object	23.Waste of substance
4. Length of non-moving object	24.Loss of information
5. Area of moving object	25.Waste of time
6. Area of non-moving object	26.Amount of substance
7. Volume of moving object	27.Reliability
8. Volume of non-moving object	28.Accuracy of measurement
9.Speed	29.Accuracy of manufacturing
10. Force	30.Harmful factors acting on object
11. Tension, pressure.	31.Harmful side effects
12.Shape	32.Manufacturability
13. Stability of object	33.Convenience of use
14. Strength	34.Repairability
15.Durability of moving object	35.Adaptability

16. Durability of non-moving object	36.Complexity of device
17. Temperature	37.Complexity of control
18. Brightness	38.Level of automation
19. Energy spent by moving object	39.Productivity
20. Energy spent by non-moving object	

Table 1

2.5 Principles for Triz

Here are 40 inventive principles [12]:

Principle 1: Segmentation

Principle 2: Taking Out

Principle 3: Local Quality

Principle 4: Asymmetry

Principle 5: Combining

Principle 6: Universality

Principle 7: Nesting

Principle 8: Counterweight

Principle 9: Prior Counter-action

Principle 10: Prior Action

Principle 11: Beforehand Cushioning

Principle 12: Equipotentiality

Principle 13: The Other Way Around

Principle 14: Spheroidality/Curvature

Principle 15: Dynamics

Principle 16: Partial or Overdone

Principle 17: Moving to a New Dimension

Principle 18: Vibration

Principle 19: Periodic Action

Principle 20: Continuity of Useful Action

Principle 21: Rushing Through

Principle 22: Convert Harm to Benefit

Principle 23: Feedback

Principle 24: Mediator

Principle 25: Self Service

Principle 26: Copying

Principle 27: Inexpensive Short-Lived Object

Principle 28: Replacement of a Mechanical System

Principle 29: Use a pneumatic or hydraulic construction

Principle 30: Flexible or Thin Membrane

Principle 31: Use of Porous Material

Principle 32: Color Changes

Principle 33: Homogeneity

Principle 34: Discarding and Recovering

Principle 35: Parameter Changes

Principle 36: Phase Transitions

Principle 37: Thermal Expansion

Principle 38: Use Strong Oxidizers

Principle 39: Inert Environment

Principle 40: Composite Materials

2.6 Biomimicry Examples of some principles

Example of Segmentation:

The articulated fronds of coralline macroalgae provided flexibility and minimize tension due to segmentation. [13]

Figure 2.1

Example of Combining:

Cacti sequester atmospheric carbon dioxide by converting it to oxalate and combining it with soil-derived calcium ions which ultimately lead to the formation of solid calcium carbonate.[14]

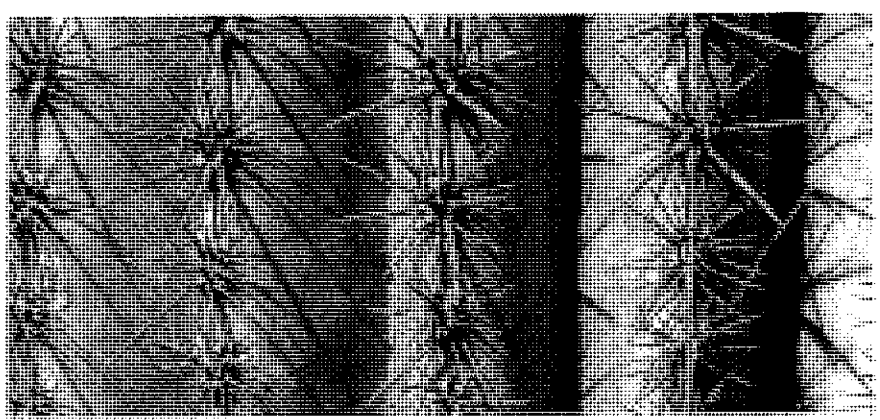

Figure 2.2

Example of Mediator:

Geobacter species "breathe" minerals instead of oxygen by transferring electrons along protein nanowire "pilli" via "electron hopping".[15]

Figure 2.3

There are many examples of the other principles which can be found in the website asknature.org. Rather than list them all here, the reader use a keyword website search.

2.6 Contradiction matrix of Triz

Using the tools as an extension of the 40 principles is the contradiction matrix to list the 39 parameters which can impact each other. The different combination of the 39 parameters can lead to certain of inventive principle. The combination of each pairing of the 39 parameters in a matrix represents a row and a column.

The main objective of the contradiction matrix is to decide which principles are most likely effective approaches to solve the generic contradiction. If we have some contradictions and want to solve them quickly, we have to use the contradiction matrix.

One of the most important things for TRIZ is that we use it as a tool when we analyze and predict the evolutionary improvements needed to develop new and successive generations of a system.

The following steps are taken to use the matrix to identify inventive principles:

1. List the parameters which will improve;

2. List he parameters which will worsen;

3. Couple the parameters into pairs;

4. Find out principles from the matrix by using improved and worsen parameter from each couple.

Without practice, an engineer could become confused about when to use the 39 parameters and 40 principles of TRIZ. An example may help reduce confusion. Keep in mind, whenever facing a technical problem, there will be contradictions, such as driving a car at a high speed and having to stop it in a short distance. The contradiction here is high speed leading to high force, contradicted by the desire to having to stop the car in a short distance, so the parameters we use here are force and length. As a result, from contradiction matrix, using the row for force and the column for length, we find that principles of 11, 18 and 21 are good candidates for generic solutions.

The following table is part of the contradiction matrix[16]:

Worsening Feature ⇨ / ⇩ Improving Feature		1 Weight of a mobile object	7 Volume of mobile object	33 Convenience of use	36 Complexity of a device	38 Level of automation	39 Capacity/ Productivity
1	Weight of a mobile object		29, 2 40, 28	35, 3 2, 24	26, 30, 36, 34	26, 35 18, 19	35, 3 24, 37
7	Volume of mobile object	2, 26 29, 40		15, 13 30, 12	26, 1	35, 34 16, 24	10, 6 2, 34
33	Convenience of use	25, 2 13, 15	1, 16 35, 15		32, 26 12, 17	1, 34 12, 3	15, 1 28
36	Complexity of a device	26, 30 34, 36	34, 26 6	27, 9 26, 24		15, 1 24	12, 17 28
38	Level of automation	28, 26 18, 35	35, 13 16	1, 12 34, 3	15, 24 10		5, 12 35, 26
39	Capacity/ productivity	35, 26 24, 37	2, 6 34, 10	1, 28 7, 19	12, 17 28, 24	5, 12 35, 26	

Table 2 Contradiction Matrix

TRIZ's 40 principles and the associated contradiction matrix has become a popular tool in some engineering design communities and has also attracted attention of inventors, so there are many usage examples found on the internet.

Inventors wanting to create something will use TRIZ. They want to make something better, so they follow the principles of TRIZ and learn how to use the contradiction matrix to lead to principles which can help the inventors formalize their approach to problem solving. This also the reason why to use as a tool combined with biomimicry, to help make the problem easier to solve.

Chapter 3

3.1 Introduction of the thesis work

For my thesis, I developed a new way to make it easier for inventors and engineers to find solutions to engineering problems. The new way of engineering problem solving principle is called "Bio-TRIZ." Engineers and biologists may want to know "Should we use it now?" and "How can we use it?"

3.2 Why we use BIO-TRIZ now

We introduced the basic principles of Biomimicry in chapter 1 and the 40 inventive principles of Triz in chapter 2. After reading these two chapters, you may have a better understanding of both Biomimicry and Triz. Biomimicry was developed for humans to follow nature's way of solving a problem when they need to solve one which would has bad effects on the environment we live. At the same time, the TRIZ technique has been wildly used to solve problems, especially in the engineering area.

Nature can be mysterious to humans, but we already know and have learned many things from nature. There are many more things we still do not know so far, and many additional properties in nature are worthy to learn, that is why we use the principles of Biomimicry. TRIZ has been a famous problem solving and improving technique in practice for almost five decades. The 40 principles of TRIZ and the contradiction matrix, all make it easier for engineers to find out the problem and solve it. One is that it is worthy for us to learn from nature, and the other is the principle that can make our problem easier to be solved. This is why I tried to combine them to solve problems.

3.3 How can we use BIO-TRIZ

It is desirable to use bio-TRIZ when we are faced with a problem and we know how to use it. In order to connect TRIZ and Biomimicry we have to know what the basic principles are for these two methods. If you do not have a good understanding of the inventive principles, you will not use it in an easy way to solve problems. Indeed, you may lead yourself into a tough result, and a non optimal result will be found. There are several steps to follow to use the methodology to solve the problems:

Step 1.

Focus on the problem and write out the problem statement;

Step 2.

Identify the contradicting parameters;

Step3.

Use the contradiction matrix to find the best inventive principles to use;

These three steps all lead to the methods TRIZ proposes to solve particular engineering problems. After these steps, we use the proposed inventive principles to connect with the methods of Biomimicry. But when we want to solve it in this way it might be very complicated to solve the problem, and we can see how complicated it will be from the following three examples.

3.4 Example before improving the methods of using Bio-TRIZ:

The follow examples are all solved problems. I use these examples here to combine my method to see if my method can solve these solved problems.

1. Robot Termites[17]

We face a problem of how to move things more efficiently? As a result, we might find that we can use inspiration from nature to help us improve the way humans move things now.

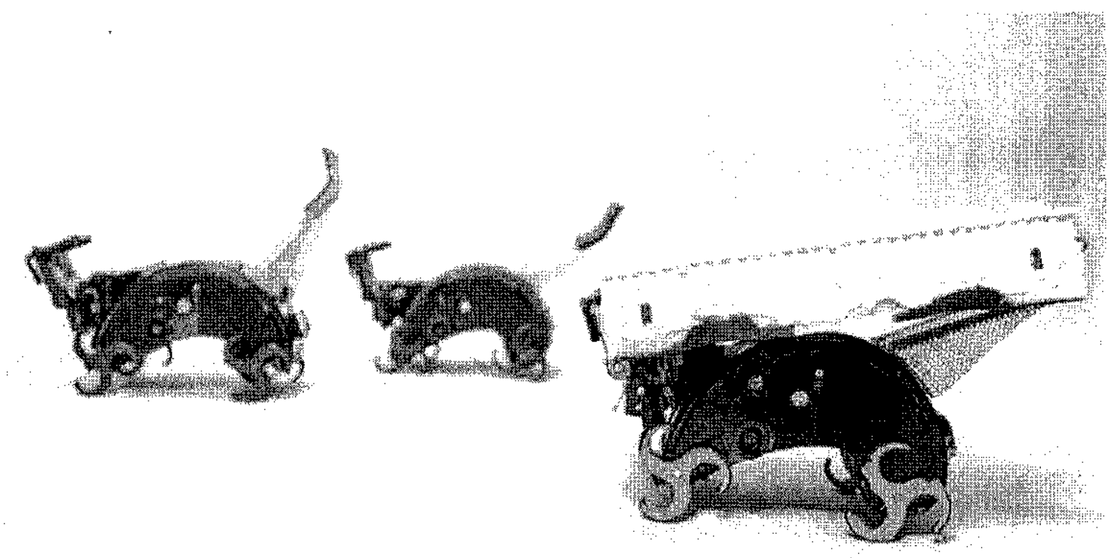

Figure 3.1

First. We have to find out the TRIZ inventive principles;

TRIZ part:

For TRIZ method, we have to find out the improved and the worsened parameters. iN this case, the improved parameter is volume of stationary and the worsened parameter may be stress and pressure.

We can find two principles from the matrix which was used.

Principles:

24. Mediator, intermediary;

35. Transformation of the physical and chemical states of an object, parameter change, changing properties.

After finding out the proposed principles to be used, we can go to the Biomimicry part.

For the problem we want to solve, we can search what we want to know from nature. For this problem, we want to know "How does nature move things?" in the ask nature website (www.asknature.org). As a result we can find out 531 related articles about how nature constructs building. Also, we need to search the two principles together, and 2707 articles would be found.

After all the related articles are found, we have to make a collection of how many different animals or insects are used in the articles for both biomimicry and TRIZ methods.

At last, we have to find out the same kind of animals or insects, then use each of them as a key word to do a search in the ask nature website.

After finding out the related articles about each one, we can compare which will be helpful to solve the problem we are facing.

As an example, we find the following animals and insects from the biomimicry part:

Dolphin, Tobacco, Seaweed, Catnip, Butterfly, Mosquito, Blister, Salmonella, Shark, Termite, Bird, Beetle, Lizard, Swift, Worm, Frog, Snail, Squirrel;

And for TRIZ part we find out the following animals and insects:

Butterfly, Frog, Bees, Scorpion, Bird, Mole, Ant, Dolphin, Bat, Tortoise, Gazelle, Snake, Termite, Kangaroo, Snail, Mosquito, Woodlice, Crocodiles, Beetle.

We can sort for animals and insects that are common to both methods, then we can search them in the website, and find the number of articles related to each type:

Butterfly: 35 related articles;

Frog: 30 related articles;

Bee: 27 related articles;

Termites: 20 related articles;

Snail: 13 related articles;

Mosquito: 21 related articles;

Bird: 59 related articles;

From these results we assume that a significant number of articles is an indication of the likelihood that a given creature may hold the key to making a solution a reality. Of course, it depends on the characteristics of each. For example, the way termites move things leads us to ideas to solve the problem here. After choosing termites, we study the characteristics the termites to find out the way termites move thing.

2. Robot Inchworm & Robotic snake scales [18]

The problem here is to find out how to climb in nature and determine the suitable idea.

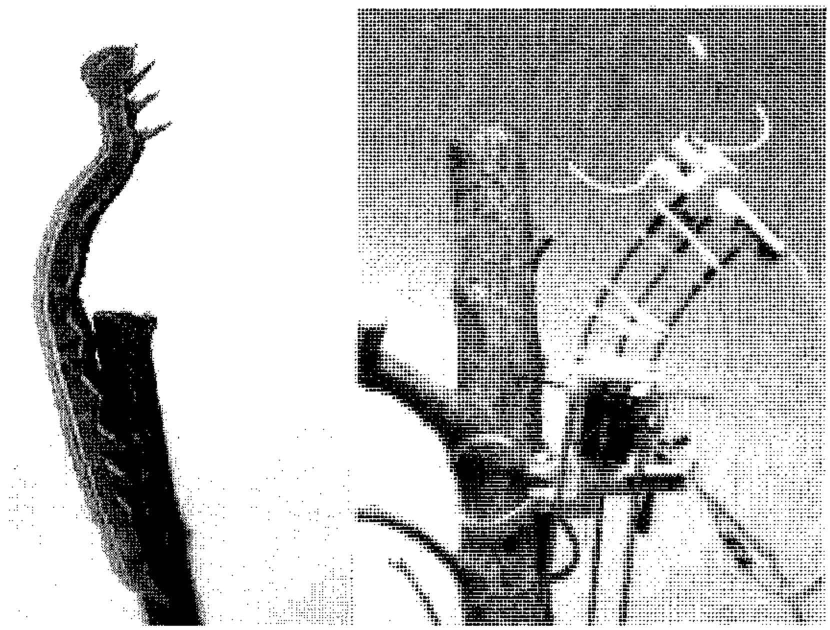

Figure 3.2

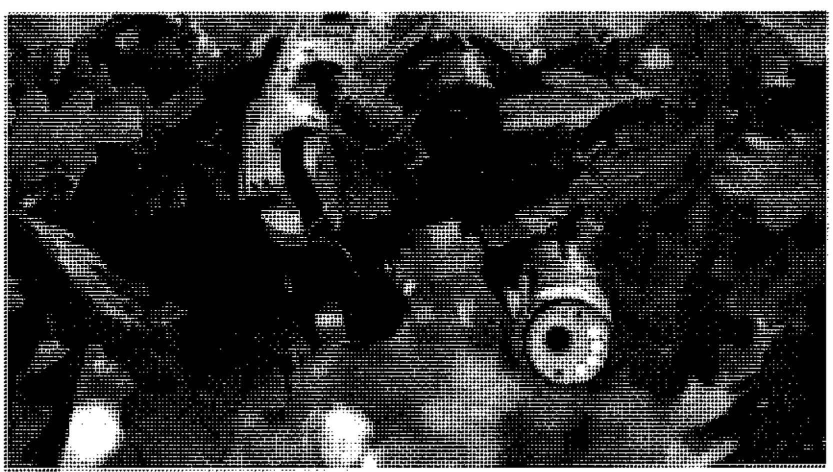

Figure 3.3

At the beginning of our search, we list the principles we have to use in TRIZ part.

TRIZ part:

Contradiction: Improved parameter: Speed Worsened parameter: Power

Then we get the inventive principles from the contradiction matrix.

Principle: 2. Separation, Segregation;

19. Periodic action;

35. Transformation of the physical and chemical states of an object, parameter change, changing properties;

38. Use strong oxidizers, enriched atmosphere, accelerated oxidation.

After that, the four principles were searched on the asknature website and 224 related articles came out.

I found the following animals and insects to be relevant:

Frog, Butterfly, Gecko, Cat, Seal, Penguin, Scorpion, Squirrel, Fly, Spider, Cow, Snail, Bat, Snake, fish, Mosquito, Termite, Beetle, Bird, Worm, Bear, Sandpiper, Snake, Lizard.

Biomimicry part:

By searching "How does nature climb?" in the website, 425 related articles came out.

The following are the animals and insects from there articles:

Dolphin, Blowfly, Frog, Sandpiper, Woodlice, Butterfly, Lizard, Beetle, Shark, Swift, Worm, Fish, Rat, Scorpion, Bee, Snake, Cockroach, Termite, Ant, Owls.

Then, I sorted the lists, looking for common items and analyzing characteristics of them. At last we can choose inchworm and snake as the idea provider for us to learn how nature climbs.

3. Robot Elephant's nose [19]

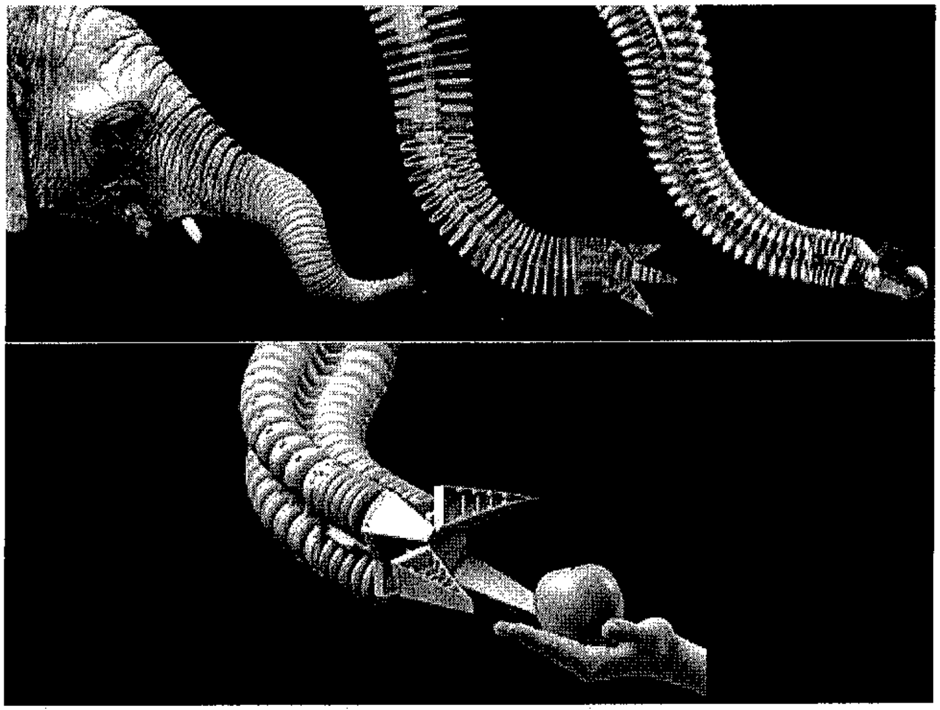

Figure 3.4

We have to find out the improved and worsened parameter for the matrix to find out principles.

Contradiction: Improved parameter: Weight of stationary object Worsened parameter: Power

Principle: 15. Dynamicity, optimization

19. Periodic action

18. Mechanical vibration

22. Convert harm into benefit

Related animals and insects:

Elephant, cat, bee, spider, snail, dragonfly, beetle, bat, frog, pelican snake;

Biomimicry part:

Here we search the key sentence "how does nature pick things", and find out 625 articles can provide ideas from nature.

Then we can find the following topics are the best idea sources to help us find out a idea: Butterfly, frog, snake, grebes, snail, ant, whirligig beetle, bat, penguin, elephant, dragonfly, flying squirrels, beetle, lion, squirrel, swift.

The number of related articles for each common animal or insect:

Elephant: 22 related articles;

Dragonfly: 12related articles;

Beetle: 58 related articles;

Frog: 30 related articles

Lastly, we can analyze the characteristics of the last four idea providers to make the choice of which idea to use.

For the three solved examples, we do not know how the original inventor found the idea to solve them, but we can see from the bio- TRIZ method we can also find out the idea. If we consistently solved problems in this way, I am confident that there would be lots of ideas for you to solve it. But it will take you a long time in comparing the similar things from the results of both biomimicry and TRIZ side.

3.5 Making Bio_ TRIZ easier to use

After working with the complicated initial method of Bio-TRIZ, I began to find a way to simplify the results of the search. I found that if I compare the results for each method and then sort for common results, it requires a lot of work and needs several steps to finish the comparison. Instead, I found a new way to solve the problem which will utilize the part of TRIZ first, and then use the results to do a search in the website of asknature to find out what nature should do to solve the problem using the TRIZ principle.

The following are the steps of how to use TRIZ and BIOMIMICRY to solve a specific problem:

1. Analyze the problem;
2. Find out all potential contradictions that the problem has;
3. Find all inventive principles from the set of contradiction pairs;
4. Type the first principles in to the asknature.org and do a search;
5. Gather all the articles that the asknature website finds and sort them into two levels. One level is "helpful to solve", while the others are "somewhat helpful." Delete all the principles that do not have a very close relationship with the problem or the principles do not have any affect for the problem;
6. Repeat step 4 for the each principles, and find of the number of the articles;
7. Do step 5 again to sort for useful principles, and search the rest of the principles;
8. Delete the principles which are not very helpful until I find the principles that are helpful to solve the problem;

9. After making sure all the principles are helpful, search again and find out how does nature solve similar problems;
10. Analyze which of the example is most feasible to solve the problem;
11. Try to apply the principle(s) in the same manner as nature to solve the problem.

For the method we would use to connect TRIZ and Biomimicry, we have to become familiar with the inventive principles commonly employed by these two methods. If you do not have a good understanding of the inventive principles, you will not use it in an effective way to solve the problems you have encountered. Indeed, you may lead yourself into a non-feasible of non-optimal solution.

3.4 Examples of bio-TRIZ after improvement

Example one:

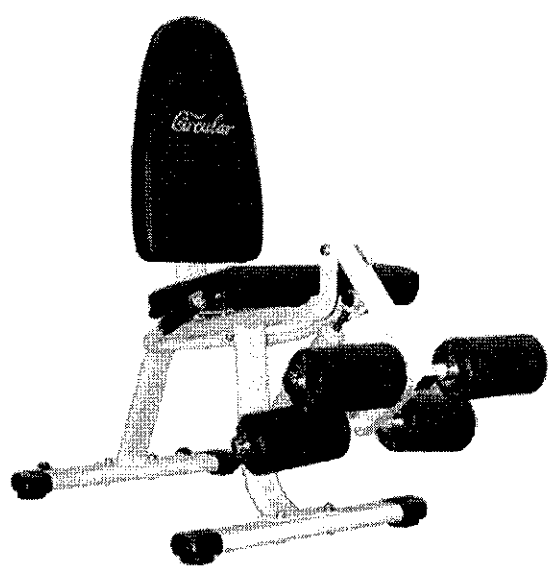

Figure 3.5

Here is an example of the bio- TRIZ problem solving method, maybe you can have a better understanding of the new approach which combines the principles of biomimicry and TRIZ as I have done:

The example problem is that we have to improve several fitness devices for the users. They can use the device easier after we have an idea to help them improve the portability of the equipment.

After reading the requirements of how to improve the fitness device, we know that we have to make these devises easier to move. I start to find the contradictions inherent with the problem. I found that parameters desired to improve the problem are the following:

1. Weight of moving object;

7. Volume of moving object;

33. Ease of operation;

36. Device complexity;

Then the worsening part of the contradictions are;

11. Stress or pressure;

13. Stability of the object's composition;

23. Loss of substance;

39. Productivity.

After that we can make contradiction pairs;

1&11, 1&13, 1&23, 1&39;

7&11, 7&13, 7&23, 7&39;

33&11, 33&13, 33&23, 33&39;

36&11, 36&13, 36&23, 36&39.

These contradictions pairs represent all the combinations associated with this problem. This is what can help lead us to the inventive principles needed to solve the fitness device problem. When we set up the couples of contradictions, we will look for them with the improving part and the worsening part in the matrix, and then find out the principles in table. The columns represent the improving part and the rows represent the worsening part. Then we can find out all the principles which appear more than twice in the contradiction matrix of this problem and list them together:

1. Segmentation

2. Extraction

6. Multi-functionality

10. Prior action

12. Equipotentiality, remove stress

17. Moving to a new dimension

19. Periodic action

28. Replacement of a mechanical system with 'fields'

29. Hydraulics

32. Changing color or optical properties

35. Transformation of the physical and chemical states of an object, parameter change, changing properties

36. Phase transformation

37. Thermal expansion

40.composite materials

When we get all of the principles from the contradiction matrix, we need to search them together in the website www.asknatur.org.

After the searching we will get 1879 related articles which are too many for us to efficiently find an idea that can help us to solve the problem. We need to pick only the most useful articles to help solve the problem. We obtained the principles show below:

2. Segmentation

3. Extraction

7. Multi-functionality

11. Prior action

13. Equipotentiality, remove stress

20. Periodic action

29. Hydraulics

38. Transformation of the physical and chemical states of an object, parameter change, changing properties

39. Phase transformation

And 1226 related articles appeared, but it is still too many, so we need delete some the principles that we deem least important or have small impact on the problem we are trying to solve:

3. Segmentation

4. Extraction

8. Multi-functionality

12. Prior action

14. Equipotentiality, remove stress

29. Hydraulics

273 articles remain, it is much better, then we do a selection once again and there are only three principles remained:

1. Segmentation
2. Extraction
29. Hydraulics

As we expected, only 19 articles appears. They have some good examples to use in the biomimicry part. After some of the good examples were found, we search the key words in the website to look for more details to get ideas.

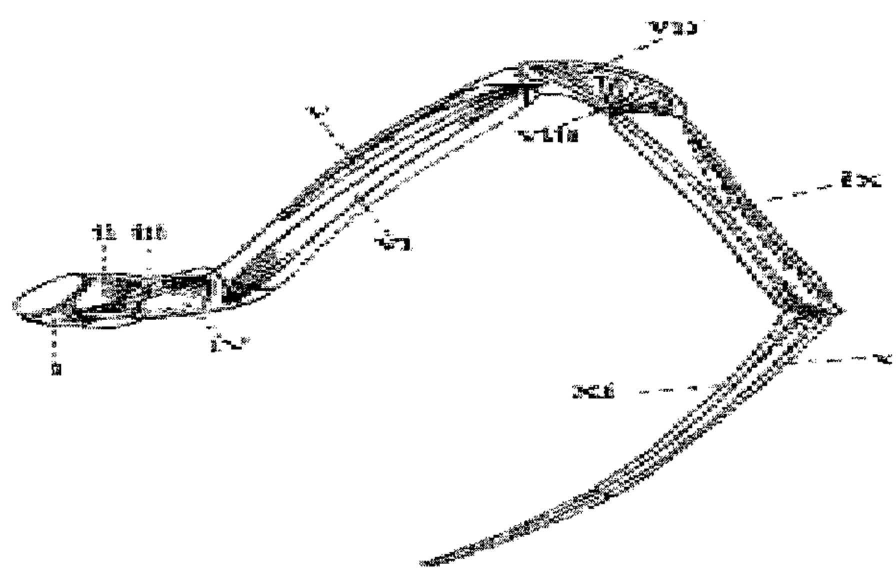

Figure 3.6

Finally, for the problem of the exercise equipment, I found that we can learn from spiders' legs to improve the device by means of a foldable device and make it smaller, and more efficiently use the strength of the material. If we improve the device in this way, it might be the best idea to solve the problem. All the principles here which were deleted is due to affect the principle have on the problem, if it affected a lot it would be used, if not it would be deleted.

The following images show the structure of the fitness device:

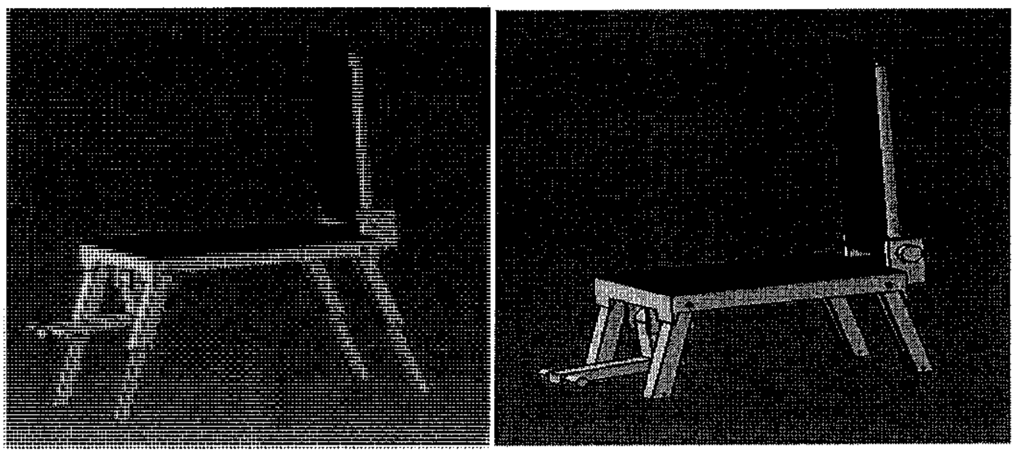

Figure 3.7

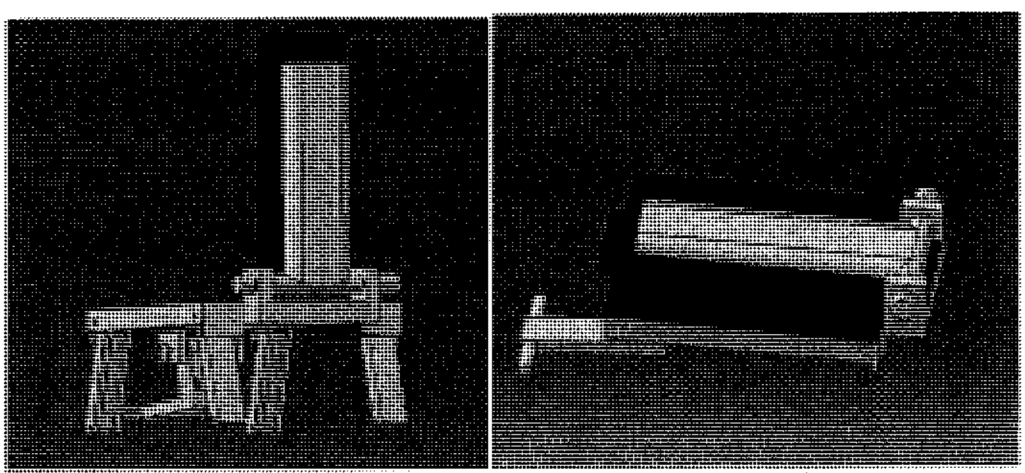

Figure 3.8

Example Two: Consuming energy

This example is to show that how can we use the improved method to find out the solution to solve a combination problem like reducing energy consumption. In this problem we have to solve seven different problems to combine them make them an efficient system to use.

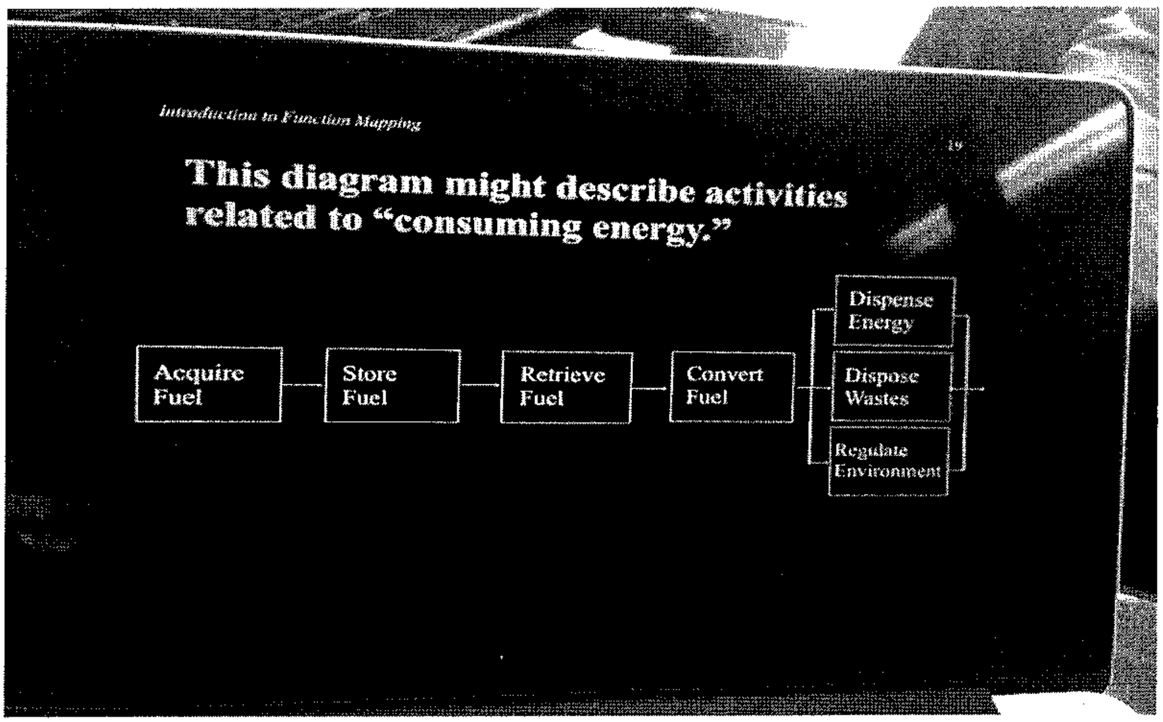

Figure 3.9

Acquire fuel is the first problem we have to solve in this system. We need to use the method we applied to the fitness device problem to solve the energy problem.

First we have to find out the contradictions of this problem:

We have to find out all the contradiction for the problem and list them as follows:

1.Contradiction: reliability & ease of operation

Principles:

17. Moving to a new dimension

27. Cheap, disposable objects

40. Composite materials

2. Contradiction: Loss of substance & ease of manufacture

Principles

15. Dynamicity, optimization

33. Homogeneity

35. Rejection and regeneration, discarding and recovering

3. Contradiction: Device complexity & ease of manufacture

Principles

1. Segmentation

13. Inversion, the other way round

26. Copying

27. Cheap, disposable objects

After finding all the contradictions we can use them to find out which inventive principles may be helpful here. Then we have to search for them in the asknature.org and then we will find a huge numbers of articles, but not all of the articles are useful. We need to delete some of the principles and then search again.

Searching all principles found: Moving to a new dimension, Cheap, disposable objects, Composite materials, Dynamicity, optimization, Homogeneity, Rejection and regeneration, discarding and recovering, Segmentation, Inversion, the other way round, Copying, Cheap, disposable objects, and 1842 articles was found.

Searching Composite materials, Dynamicity, optimization, Segmentation, Inversion, the other way round, Copying, Cheap, disposable objects

929 articles was found.

Searching Dynamicity, optimization, Segmentation, Inversion, 24 related articles were found. Then go through these articles to find out a idea to acquire fuel.

Store fuel

Contradiction: Loss of energy& device complexity

Principles

7. Nesting

23. Feedback

2. Contradiction: Extent of automation & ease of operation

Principles

1. Segmentation

3. Local quality

12. Equipotentiality, remove stress

34. Rejection and regeneration, discarding and recovering

3. Contradiction: Device complexity & reliability

Principles

1. Segmentation

13. Inversion

35. Parameter change

Searching all principles: Nesting, Feedback, Segmentation, Local quality, equipotentiality, remove stress, rejection and regeneration, discarding and recovering, inversion, parameter change, 279 articles were found.

Searching Nesting, Feedback, Segmentation, Local quality, Parameter change, 248 articles were found.

Searching Nesting, Segmentation, Local quality, 122 articles found.

Searching Nesting, Segmentation, 13 articles were found.

Retrieve fuel

1. Contradiction: Ease of operation & stability of the object's composition

Principles

30. Flexible membranes or thin film

32. Changing color or optical properties

35. Parameter change

2. Contradiction: Stability of the object's composition & ease of manufacture

Principles

19 Periodic action

35. Parameter change

3. Contradiction: Loss of energy & ease of operation

Principles

1. Segmentation

32. Changing color or optical properties

35. Parameter change

4. Contradiction: Loss of substance & device complexity

Principles

10. Prior action

24. Mediator,intermediary

28. Replacement of a mechanical system with 'fields'

35. Parameter change

Searching all principles listed:

Flexible membranes or thin film, parameter change, periodic action, segmentation, mediator, intermediary, replacement of a mechanical system with 'fields', 1525 related articles were found.

Searching flexible membranes or thin film, parameter change, periodic action, segmentation, mediator, intermediary, replacement of a mechanical system with 'fields', 1480 articles were found.

Searching flexible membranes or thin film, parameter change, periodic action, segmentation, mediator, intermediary, there were 458 articles.

Searching flexible membranes or thin film, periodic action, segmentation, mediator, intermediary, 363 articles were found.

Searching periodic action, segmentation, mediator, intermediary, 84 articles

Searching segmentation, mediator, intermediary, 2 articles were found.

Convert fuel

1 Contradiction: loss of energy& device complexity

Principles

7. Nesting

23. Feedback

2. Contradiction: Ease of operation & stability of the object's composition

Principles

30. Flexible membranes or thin film

32. Changing color or optical properties

35. Parameter changes

3. Contradiction: Reliability & speed

Principles

11. Compensate before

21. Rushing through

28. Replacement of a mechanical system with 'fields'

35. Parameter changes

Searching all principles nesting, feedback, flexible membranes or thin film, changing color or optical properties, parameter changes, compensate before, rushing through, replacement of a mechanical system with 'fields'. 1614 articles

Searching nesting, flexible membranes or thin film, parameter changes, compensate before, rushing through. 851 articles

Searching nesting, flexible membranes or thin film, rushing through. 681articles

Searching nesting in the website. 11articles

Dispense energy

1. Contradiction: Loss of energy& ease of operation

Principles

1.Segmentation

32.changing color or optical properties

35. Parameter changes

2. Contradiction: Device complexity & shape

Principles

13. Inversion

15. Dynamicity

28. Replacement of a mechanical system with a 'fields'

29. Hydraulics

3. Contradiction: Stability of the object's composition & loss of time

Principles

27. Cheap,disposable objects

35.parameter changes

Searching all principles :Segmentation, changing color or optical properties, parameter changes, inversion, dynamicity, replacement of a mechanical system with 'fields', hydraulics, cheap disposable objects 1418 articles was found..

Searching parameter changes, inversion, dynamicity, replacement of a mechanical system with a 'fields', hydraulics 1377 articles were found.

Searching parameter changes, hydraulics, and we get 7 articles to give us some examples to look for ideas.

Dispose wastes

1. Contradiction: Device complexity & ease of manufacture

Principles:

1. Segmentation

13. Inversion, the other way around

26. Copying

27. Cheap, disposable objects

2. Contradiction: Stability of the object's composition & ease of repair

Principles:

2. Extraction

10. Prior action

16. Partial or excessive action

35. Parameter change

3. Contradiction: Speed & ease of operation

Principles:

12. equipotentiality, remove stress

13 inversion, the other way around

28. Replacement of a mechanical system with 'fields'

32. Changing color or optical properties

Step 1 Search all principles listed:

Segmentation, inversion, the other way around, copying, cheap disposable objects, extraction, prior action, partial or excessive action, parameter change, equipotentiality, remove stress, inversion, the other way around, replacement of a mechanical system with 'fields', changing color or optical properties.

As a result, I found 6458 articles are related with these principles I had listed.

Step 2 Delete some of the principles are not very useful to solve the problem,and list the principles we can search for results;

Segmentation, extraction, prior action, partial or excessive action, parameter change, equipotentiality, remove stress, replacement of a mechanical system with 'fields', changing color or optical properties. I found 5794 articles may be useful.

Step 3 Delete some of the articles again, and search the rest of the principles again:

segmentation, extraction, prior action, partial or excessive action, parameter change, equipotentiality, remove stress. 915 articles was found.

Step 4 Delete and search one more time:

Segmentation, extraction, prior action, partial or excessive action, 325 articles was found.

Step 5 Search for the listed principles again:

Segmentation, extraction, 26 articles was found.

Step 6 Go through each of the articles to find out some of good inspirations from nature.

Step 7 Choose one from the ideas from step 6, as different people have different thoughts on how to solve a problem, so the choice of idea is a matter of personal preference.

Regulate environment

1. Contradiction: Difficulty of detecting and measuring & ease of operation

Principles:

2. Extraction

5. Combining

2. Contradiction: Object-generated harmful factors & measurement accuracy

Principles:

23. Feedback

26. Copying

28. Replacement of a mechanical system with 'fields'

33. Homogeneity

3. Contradiction: Loss of information & ease of manufacture

Principles:

32. Changing color or optical properties

Search all principles listed:

Extraction, combining, feedback, copying, replacement of a mechanical system with 'fields', homogeneity, changing color or optical properties, 5544 articles was found

Then delete some of the principles, after that search the rest of the principles:

Extraction, combining, feedback, homogeneity, changing color or optical properties, 1133 related articles were found.

Delete and search the listed principles again, and search extraction, plus feedback, we find 5 articles to give us ideas to solve the problem.

After finding solution to all the single problems, we then have to combine them as a system to use. As there many way to regulate environment in nature, we have to go through more articles to find out the idea which will be good enough for the problem. May be you can search how does nature regulate environment in the database of ask nature.

Due to this example, we can find a lot of inspirational ideas, there are no right answers to each problem. What we can do, is look for the most efficient idea to solve the problem we are facing. But the problem is when we try to put the problems into a system we cannot find out the most efficient or the most adjustable way to combine each of the solutions into a system, this is the subject of future work.

The following is the normal step by step graphic:

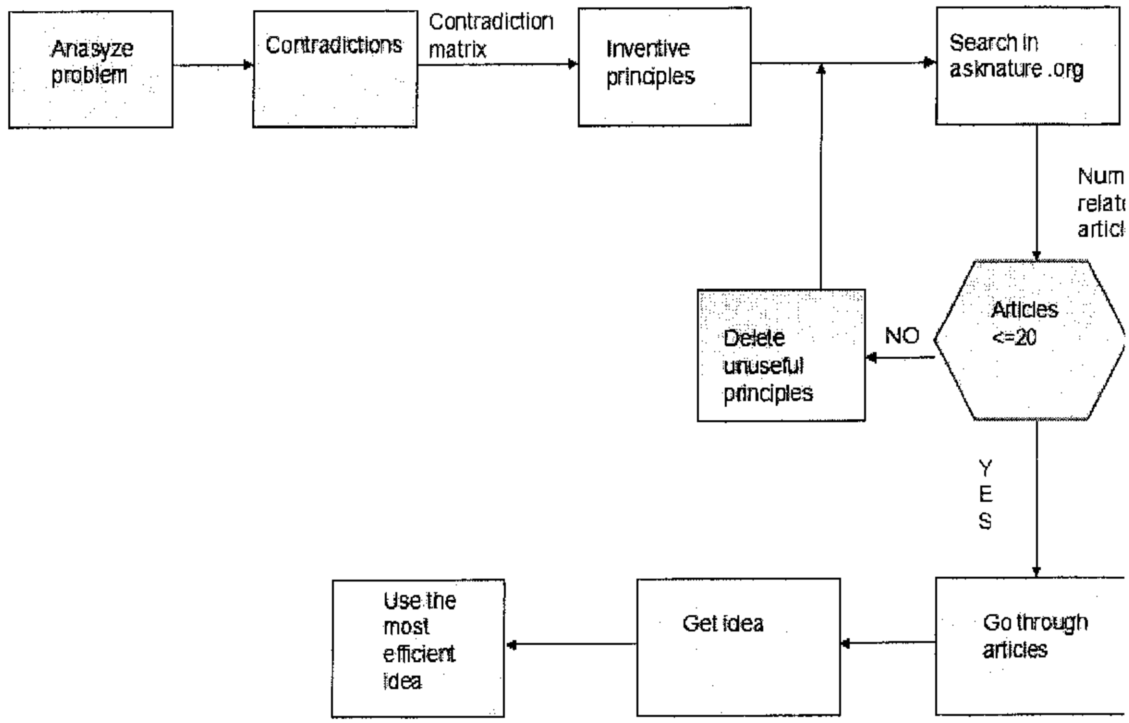

Figure 3.10

The following graphic show the steps of how to solve fitness device problem:

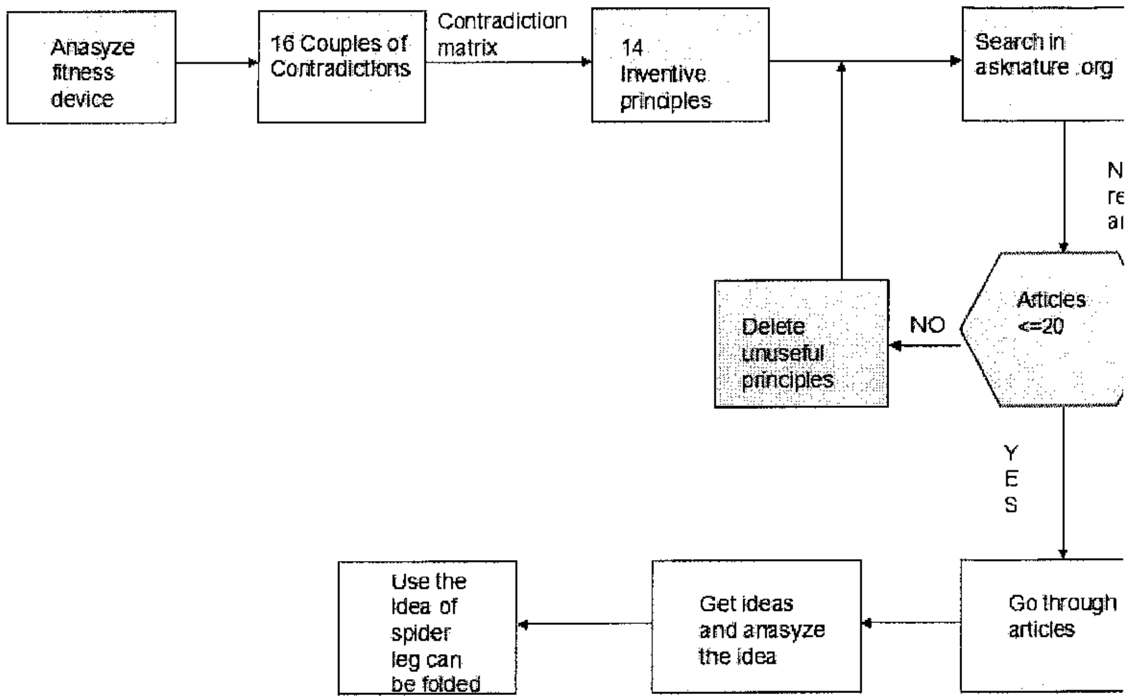
Anasyze fitness device
16 Couples of Contradictions
Contradiction matrix
14 Inventive principles
Search in asknature .org
N
re
ar
Articles <=20
NO
Delete unuseful principles
YES
Go through articles
Get ideas and anasyze the idea
Use the idea of spider leg can be folded

Figure 3.11

Chapter 4 Conclusion and future work

4.1 Summary of former work

The first three chapters represent the body my thesis. We can know more about biomimicry from chapter one. The principle of TRIZ and the contradiction matrix was shown in the second chapter. The most important part of the thesis is the new approach to use biomimicry and TRIZ by combining them, which appeared in the third chapter. As a result, Bio-TRIZ was introduced. It contains why we have to use Bio-TRIZ now and how can we use it. I believe after reading the steps of Bio-TRIZ I provided, everyone can understand it and use it to solve technical problems.

4.2 Recommendation

Most research needs a long time to finish and to get the accurate results. For my results, I have done examples of the combination between biomimicry and TRIZ, which were used in a separate way before. In my research, I provided a new approach to use Bio-TRIZ to give the inventors a way to find out the possible inspiration from nature to solve the problems they have. This does not mean that everything I have done is the right result; it is not a rigid set of principles for the researchers to apply them the same as I have applied them. I just provided them a way of thinking and they can use it in their own ways. Also, they can make an improvement of the work and make it more efficient to solve problems.

Therefore, the method I have found may not be the most efficient way to solve some problems, but it works well for solving problems like mechanical devices. Using it in a problem, which is good for this method, is very important.

Also, for my research, the most important part is the application of contradictions. It means that when you are looking for the contradictions the problem has, if you find out the wrong contradictions, it might lead you into a wrong way. You might spend a lot of time trying to find out the right result. As a suggestion, when you use some contradictions to look for the idea and it takes you a long time, that means you may be in a wrong way, the contradictions you have found might be wrong, so you need to go back and change some of the contradictions, this may help you get to the right way.

4.3 Future work

For future work, different researchers might have different thoughts of the work. They can find a way to improve the work I have done making it more efficient, or they can have their own research in a different way. The aim of the work is to use Bio-TRIZ to help us solve engineering problems in an easy way, no matter what kind of research will appear in the future. If it solves problems in an easy way, it will be the right result that researchers want.

The work I have done here might be works good for single problem, but it cannot be work good for a system as it is a combination by several problems. We have to do the future work in these three aspects as following:

1. Make the method more efficient;

2. Find out a way to make a standard way to choose a idea from nature to solve the problem;

3. Find out a method to solve the system problem in a more efficient way.

4.4 What I have learned

After the research of this thesis, I have a good understanding of biomimicry, know more how to use the principles of TRIZ, and know more about the contradiction matrix. Also, I begin to think of solving problems by using the way Bio-TRIZ. This will be the most important changes that I got from the thesis, and it will affect me in my career, and help me think and solve problems in nature's way.

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