Transdisciplinary Engineering for Resilience: Responding to System Disruptions
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Transdisciplinary Engineering for Market Development

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Abstract. Transdisciplinary engineering is composed of analysis and synthesis. Most of current engineering is focused on analysis and based on Euclidean Space, mathematical solutions are developed for product development. But if we pay attention to synthesis or design, we cannot satisfy the requirements of orthonormality and Euclidean distance with units. This paper discuss how we can challenge transdisciplinary engineering for market development, which requires Non-Euclidean Space approach.

Keywords. Transdisciplinary Engineering, Synthesis. Design, Market Development, Non-Euclidean Space

Introduction

Engineering is composed of two main fields. One is product development and the other is market development. But currently most engineering efforts are paid to product development. In other words, product development can be described as analysis and market development as synthesis.

In analysis, we look for how we can organize our tools and knowledge and focus on how we can achieve the goal effectively. Thus, the goal is fixed from the first and we pay our efforts to find the best HOW to produce better products in a shorter time and with less cost. It is problem solving. Synthesis is design and we look for WHAT product we should develop. It is goal finding and problem setting. Thus, it calls for trials and errors. And in analysis, we go deeper and deeper. But in design or market product, we need to look wider and wider to find out a new market with the currently available resources.

Thus, market development is nothing other than exploration. President Theodore Roosevelt, who is also famous as explorer, left the following famous words,

Do what you can, with what you have, where you are.

We need to make efforts to find out WHAT we should do, and we should consider WHY we are trying to explore.

S-growth curve is well known, and most engineering now is focusing on analysis or product development. Goal is fixed from the first and HOW we can produce better products effectively is focused. Thus, with time, product development accelerates and finally it reaches the ceiling, and we start to look for another product to develop. But in market development, the form is trapezoidal. And we need to find a market that grows immediately with lifetime as long as possible (Figure 1).

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Figure 1. S-curve and trapezoid.

Transdisciplinary Engineering for product development follows s growth curve and engineering there is tree-structured. As the goal is fixed from the first and the goal is single. It is nothing other than a tree. So, how we can assign appropriate tools is important. If appropriate tools are not available, we need to develop them. Thus, the process goes on, the development grows in the form of letter S. In product development, Trans- in Transdisciplinary means to look at tools from a higher viewpoint.

But Trans- in Transdisciplinary Engineering for market development means middle or media. Thus, it is deeply related to communication. In fact, Kevin Ashton proposed IoT (Internet of Things) [1]. This internet means nothing other than communication. Ashton worked in supply chain management. So, it is market engineering. He pointed out also that it is important to work with machines on the same team as Things Team. So, we need to communicate with machines.

This paper points out that to explore market, we need to evaluate performance of each candidate model and compare and prioritize them to make a strategic decision. And a new approach called Mahalanobis Distance-Pattern (MDP) Approach is proposed.

1. Our World is Changing

Our world is changing frequently and extensively.

(1) Yesterday, there were changes. But they changed smoothly, so that we could differentiate them and could predict the future. Engineers could foresee the operating oruse conditions of their products. So, they could focus their attention on their functions. So, engineers focused their attention on how they can control them and secure reproducibility.
But today, changes are sharp, so we cannot differentiate them. We cannot predictthe future anymore (Figure 2).

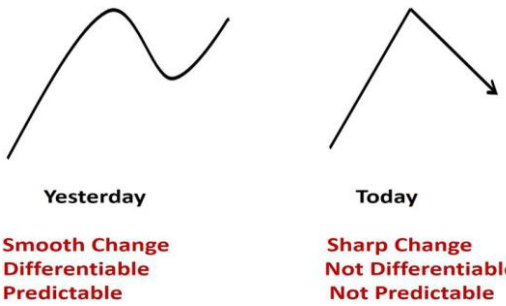

Figure 2. Changes of yesterday and today.

(2) Yesterday, our world was closed with boundary. So, we could apply mathematical approaches in a straightforward manner. But our world keeps on expanding and now it becomes open world without boundary. When the world was not so wide open, we could apply system identification approach, so we could manage to apply mathematical approaches.
System identification shares the same idea how we identify the name of a river (Figure 3). If we look at the flow, it is changing every minute. So, we cannot identify its name. But if we look around, we find mountains and forests and we can identify its name.

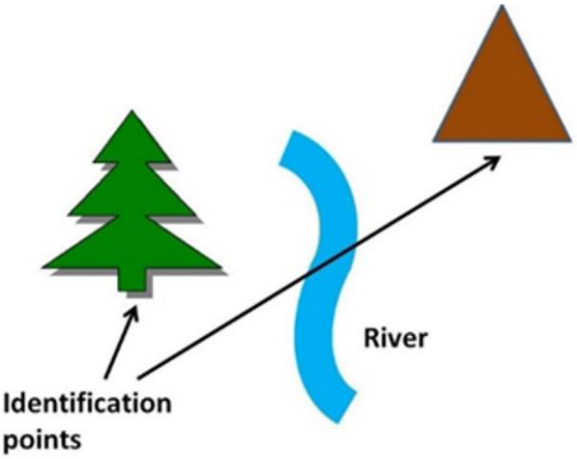

Figure 3. How we identify the name of a river.

This approach worked very well. But now our world is changing frequently and extensively and in a unpredictable manner. So, in short, now we are thrown into the flow. How should we manage to get to our goal? This is the challenge we are going to discuss here.

(3) Materials are getting softer and softer.
Materials used to be hard. So, even from a distance, we could understand how we should maniputate them. But today, materials are getting softer and softer, so that we cannot understand how we should manipulate them. Vision alone does not work anymore. We need to directly interact with them to decide how we should deal with them. When we try to pick them up and it does not work then we need to scoop them, etc. Direct interaction becomes crucial.

2. Euclidean Space Approach

Most engineering research are based on Euclidean Space approach. It requires orthonormality on all datasets and it is based on interval scale with units. And datasets are related. So, when the dimensions are small, we can obtain wonderful results, but then from there we cannot step forward easily. This is called either Devil River, Valley of Death, or Darwinian Sea. It means there is a big gap between the basic research and industrialization.

In fact, when the number of dimensions increases, the curse of dimensionality emerges, and we cannot solve the problem mathematically. Then, how can we solve the problem against the curse of dimensionality? The curse of dimensionality emerges because we stick to the Euclidean Space. Then, how can explore Non-Euclidean Space?

3. Non-Euclidean Space Approach

3.1. Pattern

Shuichi Fukuda and his group carried out a research to detect emotion from face. They tried many image processing techniques, but they took too much time and without satisfactory resulsts. Then, Fukuda suddenly realized that we can detect emotion from cartoon characters at once. At that time, most cartoons aere just in black and white, but we could immediately understand their emotion. So, we developed a carttoon model approach and we succeeded in detecting emotion in a very short time and without any difficulty [2], (Figure 4). At this time, we used Euclidean Space and cluster analysis.

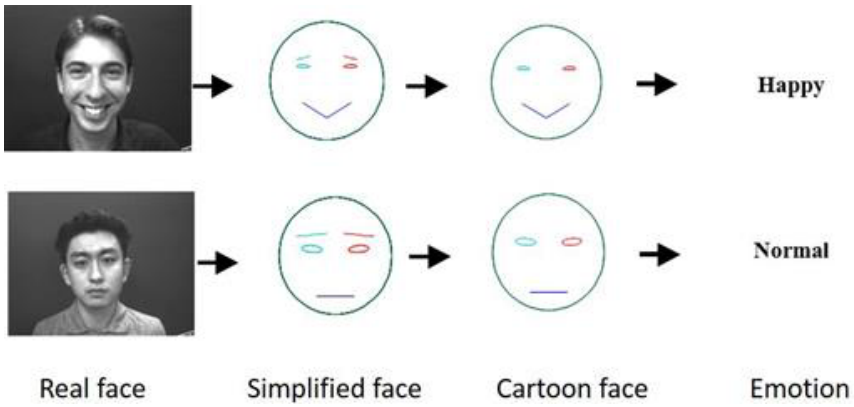

Figure 4. Detection of emotion from face using cartoon model.

3.2. Mahalanobis Distance

Mahalanobis proposed Mahalanobis Distance, which is ordinal scale [3]. Its purpose is to remove outliers and to improve design of experiments. So, his original paper is to improve Euclidean Space approach. But if we note that his distance is not Euclidean distance, i.e., interval scale distance with unit and that it is ordinal scale, we can utilize it as Non-Euclidean Space approach.

Mahalanobis Distance (MD) is defined as how far away the point P is from the mean of the dataset as shown in Figure 5. And MD does not call for its dataset to be orthonormal. Any collection of data is allowed. As customers have a wide variety of preferences or expectations, this distance can provide a truly adaptive performance indicator. In fact, the idea of KPI, Key Performance Indicator, plays a very important role in business. So,MD is a perfect fit for market engineering.

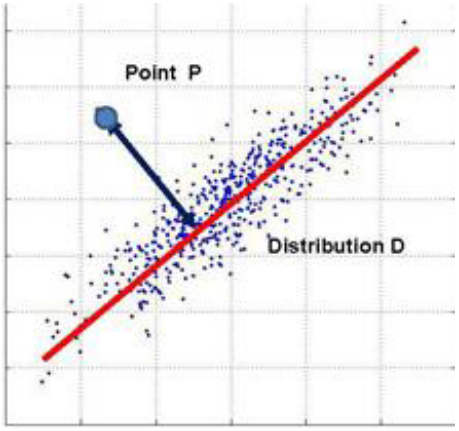

Figure 5. Mahalanobis Distance.

3.3. Mahalanobis-Taguchi System

Around the same time when Fukuda and his group developed pattern-based cartoon model, Genichi Taguchi, founder of quality engineering, developed Mahatanobis-Taguchi System [4]. His idea was unique.

In quality control, it has been a tradition to control quality element by element. But in practical applications, most industries find it very difficult to carry out element by element quality control. What they can do is to manage quality holistically.

Taguchi realized if he introduces MD and combine it with pattern, he can respond to their needs. Let me explain using an example of number. We write number 2 differently from time to time and from person to person. But if we average these samples, we can obtain a standard pattern of number 2. Taguchi calls this standard pattern Unit Space (Figure 6). And he introduce Threshold. If MD is smaller than this threshold, then we can identify the letter as number 2. If it is larger than the threshold, we cannot (Figure 7).

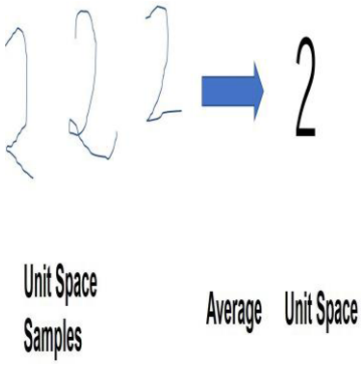

Figure 6. Defining Unit Space.

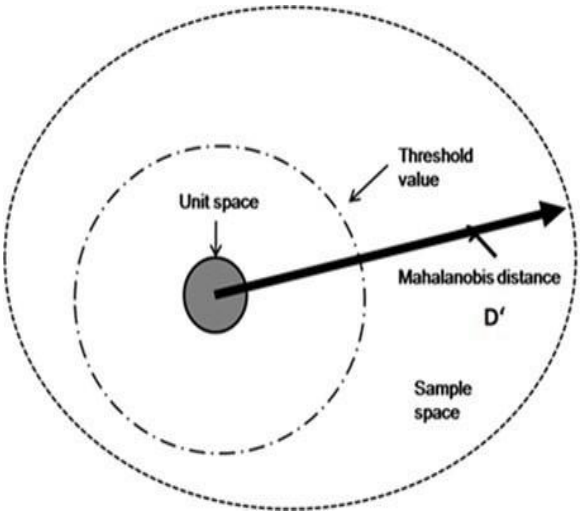

Figure 7. Mahalanobis-Taguchi System.

4. Performance Evaluation

Yesterday, customers were called Consumers, because their needs were material-focused. They wanted products. But as Abraham Maslow pointed out [5], Human needs shift to mental satisfaction and we finally look for Self-Actualization (Figure 8). Edward Deci and Richard Ryan proposed Self-Determination Theory [6] and made it clear that if the activity is internally motivatedand self-determined, we have the maximum satisfaction and sense of achievement, which no external rewards can provide.

Figure 8. Maslow's hierarchy of human needs.

When we wanted products, the goal is fixed from the first, so we can sell our products based on a tree structure. What we needed was to assign persons best fitted to the position (Figure 9). But the changes become frequent, extensive and unpredictable, so, we need to organize a team which adapt to the environments and situations flexibly and adaptively.

Amy Edmondson at Harvard Business School pointed out our team organization and management have been too much static. If we consider the current situation of frequent, extensive and unpredictable changes, we need to introduce dynamic team organization and management. She calls it Teaming [7].

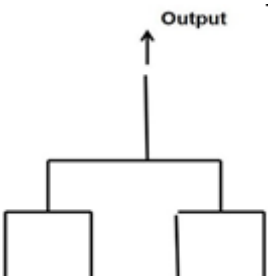

Figure 9. Tree.

Thus, teaming organization and management have to be a network, because our goal varies from case to case and from time to time (Figure 10).

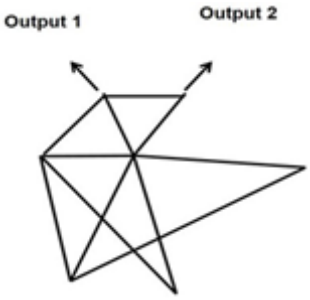

Figure 10. Network.

5. Conclusions

Mahalanobis Distance Pattern (MDP) Approach is basically the same as MTS. But MTS is static pattern matching. MDP, on the other hand, focus on dynamic variation. Instead of static pattern, we take up dynamic pattern variations and we calculate MD in the same way as in MTS. Then, we can have the dynamic pattern variation. And we evaluate performance. MTS provides static performance indicator, while MDP provides dynamic one.

As this paper is focused on Transdisciplinary aspect [8][9], the details of MDP are not described here.

For its details, visit [10].

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