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Mahalanobis Taguchi Fukuda Approach to Motion Control

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As the environments and situations change frequently and extensively and these changes are unpredictable, interaction with the outer world increases its importance. Yesterday, changes were smooth, so they are mathematically differentiable, and we could predict the future. Thus, reproducibility was important, and we could develop model-based approaches. But situations being such, adaptability becomes increasingly important. In the case of motion control, coordination or balancing becomes important, but there is very few, if any, researches on how to learn to control motions. Most researches present the successful cases. But to learn to control, we need an approach to learn by trial and error, or, to learn from failures. Shuichi Fukuda proposed a new approach by extending Mahalanobis-Taguchi approach.

1. Introduction

It is pointed out in this paper that changes yesterday and today are different and changes today are unpredictable. Further, motion control is related to the problem of coordination or balancing. When our world was closed with boundaries, it was easy to develop a model and to solve the problem analytically.

But today changes are unpredictable, so adaptability is increasing importance. To cope with such changes, interaction with the outer world should be taken into consideration. But since the environments and situations change frequently and extensively, and unpredictably. What is needed now is not knowledge, but wisdom.

To be wise, we need to learn from failures. We solve the problem by trial and error. But there are very few approaches to support us to learn from failures.

Shuichi Fukuda extended Mahalanobis-Taguchi approach to learning from failures and proposes here the new approach Mahalanobis-Taguchi-Fukuda approach. This approach will be effective even in such an environment and situation of swmming, which is almost impossible to apply traditional model based approach.

2. Motion Control: What are the Issues?

Although there are many measurement tools for motion control, they only show us the successful motions. We do not understand how we can learn to control our motion to this final success.

Nikolai Burnstein pointed out human motion control is very difficult due to its large number of degrees of freedom. Fig.1 shows his famous cyclogram of hammering.

Fig. 1 Human motion of hammering

As this cyclogram shows, human motion trajectory varies widely every time, but near the target, the trajectory is fixed, i.e,. the number of degrees of freedom of trajectories is very large far away from the target, but it is reduced to the minimum near the target. The large number of degrees of freedom is to balance a body.

In other words, balancing plays a very important role in human motion control. Bernstein used the word “co-ordination” [Bernstein 1967] and he emphasized how important co-ordination, or balancing is.

Apart from such jobs, humans need balancing to move in daily life. Therefore, we need to know how we can secure balancing in the case of humans, But the mechanism of proprioception or deep sensation is still not clear.

Although Bernstein did not point out, but we may safety say that current engineering is based on the model when human motions are fixed near the target. As the number of degrees of freedom is reduced to the minimum, we can easily apply mathematical analyses. But with the rapid expansion of our world and disappearing of boundaries, engineering is shifting from an individual machine/product to a team machine/product. Therefore, the number of degrees of freedom increases exponentially. Thus, our world is shifting from explicit to tacit or from verbal to nonverbal. Thus, balancing or coordination is a critical problem in engineering, especially in robotics.

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Thus, what is missing today in motion control is how we can learn from failures. We learn to control motion by trial and error. So, we need a support tool to gudie us how we can balance better the next time. The current one only shows the final successful motion and does not provide any clue how we can do that.

Italians, Cecilia Laschi for example [Laschi 2012], [Laschi 2016] proposed Robosoft. Current robotics are based on a model approach or knowledge-based approach. But they insist that as environments and situations change frequently and extensively and in an unpredictable manner, such interaction-focused approach is increasing importance as we see in the octopuses. Octopuses make decisions how to adapt by trial and error. When their baby is born, parents die. So, there is no knowledge transfer from generation to generation. Further, octopuses have eight arms. If we study how they can coordinate these arms to perceive and understand the situation and to act to adapt to that current situation, it will help us to develop new tools for engineering which is quickly becoming multi-dimensional.

This problem is associated with the fact why we do not have swimming robots. Water changes every minute and our traditional engineering approach of system identification cannot be applied. But we learn to swim by trial and error.

Thus, how we learn to coordinate, or balance motion is a pressing issue today. This paper proposes one approach which works good for human motion control and is expected to be useful for wide applications in learning how to control motions.

3. Changes Yesterday and Today

There were changes yesterday. But changes yesterday were smooth so that they were mathematically differentiable. Therefore, we could predict the future. So, we could develop a mathematical analysis model, and solved the problem algebraically.

But changes today are sharp. So, we cannot differentiate them. Thus, we cannot predict the future. And adaptability becomes more important than reproducibility. We need to develop adaptive network in an age of teamworking to cope with this situation.

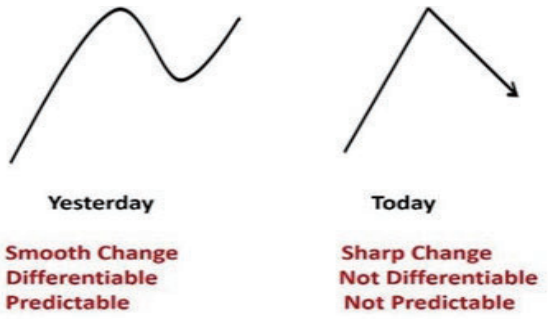

Fig. 2 Changes yesterday and today

4. Mahalanobis Taguchi Fukuda Approach

4.1 Mahalanobis-Distance

As space is limited, detailed explanation of Mahalanobis Distance (MD) is omitted here. The YouTube video [Clapham 2016] illustrates very well what MD is and how useful it is. In short, MD enables us to measure multivariate dimension variables.

4.2 Taguchi - Pattern Identification

Genichi Taguchi realized that Mahalanobis Distance is very useful for pattern identification. Patterns are multi-dimensional, and these dimensions are well defined [Taguchi 2002]

4.3 Fukuda – Learning from Failures

Taguchi set up a threshold MD and if MD of a pattern is within the threshold level, then it is identified as the same pattern. If MD exceeds the threshold, that pattern is different.

Fukuda regards musculoskeletal system as a pattern, although most robotics researchers use it as a basis for their model. Learners observe the change of MD. Successful motion varies from person to person, but we can utilize the generally accepted successful motion as a reference pattern for defining threshold. If learners control their motion to reduce their difference of MD and get closer to the threshold level, then he is improving. When he finally succeeds to control the motion, then we can set up his own threshold level.

5. Summary

Engineering and Robotics tomorrow should shift focus from nodes to links, if we use graph theory terms. Traditional engineering has paid efforts to make each node (model) richer or to advance its model further ahead. But in such environments and situations, where unpredictable changes occur frequently and extensively, i.e., our world is becoming nonverbal and increasing the number of degrees of freedom, we must develop sensors and actuators which directly interact with the outer world in multiple ways, just as the octopus does. We should study how we can increase the number of links or how we can enrich them. Thus, engineering is shifting from node-based to link-focused.

Such a shift calls for pragmatic approaches. We need to advance by trial and error. Thus, learning from failures becomes very important. We must develop approaches which help us to understand how we can control better next time by trial and error.

Shuichi Fukuda proposed here to extend Mahalanobis-Taguchi Approach to motion learning. We should extend it from pattern identification to pattern creation.

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