IT Revolution and Cybernetics Education

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1 INTRODUCTION

IT Revolution becomes a dominant key word in almost all sectors of human activities representing a major trend of changing society. Perhaps, it gives the most serious impact on the socio-economic sector where IT revolution is expected to initiate a global political-economic transition towards the so-called *digital capitalism.*

The engineering sector has been less influenced by IT revolution, because engineering has already experienced and exercised computalization in its full width and depth. In some sense, almost all aspects of IT are already in routine practices of daily life in engineering and manufacturing. Nevertheless, the new trends like *open systems* and *defact standards* which are due essentially to IT lead substantial transitions in many fields of engineering.

In control engineering practices, specially in process control, the PLC and DCS which have been strongly costumer-oriented are now gradually moving towards standarization and package-oriented. The advanced IT tools make it more economical to accommodate standard packages for implementing control systems than to create costum-made systems. This is an apparently important consequence of IT revolution in control engineering.

IT revolution influences control engineering in much broader context in future. In control education, we must be aware of the possibilities brought by the IT as a infrastructure. We must promote the attractiveness of control engineering in face of the mega trend led by IT.

2 Standarization vs Universality

Standarization is regarded as one of the significant aspects of the IT. Standarization is much older than the IT. Actually, mass production requires standarization in all aspects of manufacturing. For instance, a part of a machine can be exchanged by another simply because the part is standarized in size, shape, material and so on. Recently, the trend for standarization goes to the national, or even tansnational, level. The IT thrusts the standarization further beyond the manufacturing through standarization of software. Standarization of business, finance and management is really a new trend brought by IT revolution. But again, it is important to note that the IT is essentially a tool or an infrastructure. The important thing is the philosophy of how to use this powerful tool.

It is unquestionable for control people that control is a universal discipline. Quite a large portion of human activities can be regarded as a sort of control. It is important in

the current situation to emphasize the universality and/or ubiquity of control specially in education, in face of the strong tide of standarization.

In the history of control, we have at least three occasions where the universality of control was fully recognized. The first was the start of modern economics when Adam Smith explained the mechanism of the market in terms of feedback. He claimed that the supply and demand are naturally balanced by the action of feedback and a natural price of commodities including wage is automatically achieved. He called this mechanism of the market *invisible hands.* Actually, Adam Smith's famous book titled *Wealth of Nations* was published almost at the same time as Watt's centrifugal governor became popular. Since Watt and Smith knew each other and shared the same intellectual atmosphere of that age, it is conjectured that Smith's invisible hands were born as an outcome of the analogy with the Watt's governor. Whatever the conjecture is true or not, the attainment of equilibrium which is a fundamental issue of economics is explained by the same principle used in the governor. It was clearly a demonstration of the *universality of control.*

The second occasion was the invention of feedback amplifier in 1920's which made a great impact on communication engineering. The discovery that the feedback circuit made the amplifier stable, powerful and reliable led to theoretical study of feedback. Feedback was no longer a simple practical discipline, but a concrete theoretical notion. Communication and control shared the same principle at that time. This was also a clear demonstration of the *universality of control.*

The third occasion was the advent of cybernetics just after the second world war by Norbert Wiener. He attempted to unite various fields like phisiology, computation, communication and control engineering, and create a new field called *cybernetics.* It seems to me that the main motivation of his attempt to create a new discipline was the discovery that the animal movements of limbs were governed by the same principle as the control of machine, e.g., radar tracking gun point systems. He was proud of himself for this discovery in his famous book [1]. Again, this was a demonstration of the *universality of control.*

We have noted three occasions in the history of control where universality of control has been recognized and emphasized. Economics, communication and phisiology were the main domains of demonstrating universality, respectively. Table 1 summarizes these occasions.

Years	Focus	Field	Person
1780-90	Market	Economics	Smith
1925-35	Feedback Amplifier	Communication	Black
1945-50	Cybernetics	Phisiology	Wiener

Table 1 Demonstrations of Universality of Control

I believe that it is important to emphasize the universality in control education. Also, it is now the time to pursuit the universality at higher level based on the achievements of modern control theory.

3 Models Connecting Real and Virtual Worlds

Looking back the three occasions in Table 1, we notice that the notion of feedback played a crucial role. Ubiquity of control is almost synonym of ubiquity of feedback. However, control is by no means a synonym of feedback, though feedback is a deep notion which has been the main target of study in control theory.

Some control actions, however, do not use feedback signal at all, e.g., sequential, feedforward, programmed etc, but these are given theoretical ground by the model of the plant to be controlled. *Model* is really the key notion of control which did not exist in the era of cybernetics. Modern control theory is essentially model-based, in the sense that the design of control is carried out based on the model of the plant. If the plant is exact and disturbance is precisely measured, in other words, if there is no *uncertainty* about the plant to be controlled, there is no need for feedback. This fact actually explains the need for models in control. The model makes feedback irrelevant under perfect information. Uncertainty is the only motivation for feedback. Since uncertainty is the essential feature of our daily life, feedback is an effective means to cope with uncertainty.

In the IT, model is used for creating the *virtual world*. The swollen virtual world sometimes dominates the real world. This is one of the vicious aspects of the IT, as many critics say. In control, models also create virtual world, but it is a framework of applying logical reasoning. Furthermore, in control, the virtual world created by the model must always come back to the real world through implementation of controllers. In this sense, the consistency between the virtual and the real worlds must be preserved. This is essentially what robust control has achieved recently.

The model is a key issue in almost all human activities related to computers. In IT, model tends to widen the discrepancy between the virtual and real worlds, while in control model is always made in such a way that the virtual world it creates is consistent with the real world. The control education must emphasize the role of models and feedback in conjunction with uncertainty.

4 Cybernetics Education

It is likely that a new cybernetics will emerge through the interplay between control theory and computational neuroscience, which may lead to an integration of various fields. The dream of Norbert Wiener may revive in much broader scale and higher level than he himself thought 50 years ago.

Correspondingly, control education is expected to shift from engineering to broader scope including at least economics, finance and phisiology, emphasizing the universality of control. The key notions are *feedback* and *models*. The elementary course on feedback must include the following subjects:

1. Market mechanism by "invisible hands"
2. Amplification by feedback
3. Human motor control in the brain
4. Models as an interface between real and virtual worlds

5. Feedback as a means to cope with uncertainty

An advanced course of control must include modeling as an essential part. Instead of lecturing details of the modeling tools, the course preferably clarifies the essential meaning and roles of model as an interface between the real and virtual world. It is expected to emphasize that control is the field where the model is treated in the most appropriate and effective way.

5 Conclusion

Cybernetics was an unsuccessful attempt to combine various disciplines in a unified way to create a new paradigm of control. Various fields in the sphere of cybernetics at that time went towards specialization rather than unification. Control has been specialized mainly in engineering. Modern control theory was almost confined within engineering, and accumulated a number of remarkable and useful results. Now, time is ripe to make a new attempt to create a new field based on the universality of control. Feedback and model would be key notions representing the features of such an attempt. It may be called a *new cybernetics.* Control education is hopefully organized in conformable with this new cybernetics.

References

[1] N. Wiener, *Cybernetics*, John Wiley & Sons, Inc. 1948.