# A Defects Investigate of Classic Turing Machine Model and Its Extension in Virtualization Environment

Xiaorui Wang, Qingxian Wang, Xiaolong Hu
China National Digital Switching System Engineering and Technological Research Center
Zhengzhou, China
henanwxr@sina.com

Jianping Lu
Chongqing Communication Institute
Chongqing, China
lu8311@yahoo.cn

***Abstract*—The classical Turing machine model has defects in centralized control, sequential and determinate execution. So it is difficult to describe the computing in parallel environments and interactive systems. In this paper, we introduce several ideas for the extension of the classical Turing machine model, including three aspects: the input and output, process of state transformation and transformation rules. Focused on two aspects of scheduling method and the interaction model, we compare the differences in state control rules between the classical Turing machine model and the Internet model, then trying to extend the classical Turing machine model with the help of the network model. Finally, we introduce the role of virtualization in the implementation of the network Turing machine model.**

***Keywords-classical Turing machine model; unified scheduling; state transformation; network Turing machine model; virtualization***

## I. INTRODUCTION

From a mathematical viewpoint, computation is a process that produces the corresponding output with some input after a certain transformation rule. These transformation rules can be derived from the observed experimental, statistical analysis, logical reasoning and biology imitation. With the extension and the effective use of new transformation rules, it comes true that the Original complex problems gradually get better results. Such as in the process of solving the NP problem of traveling salesman problem, along with the use of the greedy, dynamic programming, backtracking, branch and bound, as well as the research and utilization of genetic phenomenon and ants activity, the optimal results are also gradually approaching the theoretical results.

Computation rules have a direct impact on the computation results, so it is very important to study the extension of the new rules on computation. Such as the study of the laws of quantum activity leads to the generation of quantum computing and quantum computer, which will play an important role in quantum communication and quantum cryptography; the study of the molecular structure of DNA has led to the rise of bio-computer, and it provides the possibility of parallel computing with large-scale [1].

The new emerging mode of computing has brought the consideration that physical and chemical processes in the nature or activities in human social both imply information processing mechanism, it is possible to take advantage of these processes for computing if the corresponding computational model could be abstracted[2]. The classical TM (Turing machine) model provides the reference for the implementation of the computer system structure, it contributed to the great achievements of modern computer technology. However, the classic TM model gradually shows its limitations in many facts for solving the practical problems, and becomes the bottleneck which restricting the development of computer theory and technology.

At first, this paper analyzes the defects of the classical TM model and summarizes that the general characteristics of the classical model is centralized control. Then we extend the computing capability and computing model of the classical TM under the enlighten of the characteristics of distribution and autonomy in Internet, and try to consider the factors of group participation. Finally, we discuss the specific role that virtualization technology played in the implementation of this extension.

## II. CLASSICAL TM MODEL AND ITS DEFECTS

### A. Model description

As shown in Figure 1, the physical model of the TM consists of three parts:

*1) a finite state controller*
*2) an input tape containing infinite squares.*
*3) a read and write header*

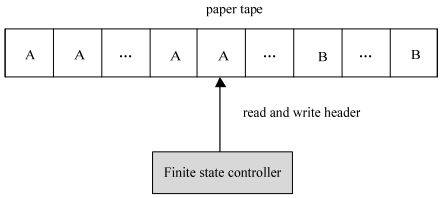


Figure 1. The composition of the TM model

One move will complete three actions: change the status of finite controller; print a symbol in the current grid; move the read and write header to the right or left grid.

The TM is a seven-tuples [3], $M = (Q, \sum, \Gamma, \delta, q_0, q_{accept}, q_{reject})$, , among them: $Q, \sum, \Gamma$ are finite sets. The key definition of the TM is the transfer function $\delta$, which specifies the machine how to go from one step to the next, the form of $\delta$ is:

$Q \times \Gamma \rightarrow Q \times \Gamma \times \{L, R\}$, that is: When the machine is in state $q$, the grid where the read and write header pointing at contains the symbols $a$, then if $\delta(q, a) = (r, b, L)$, the machine write down the symbol $b$ to replace the original symbol, then it enters the state $r$, the component $L$ or $R$ indicates that the read and write header will move to the left or right after writing the paper tape.

It can be seen from the definition and working mode of TM, the finite state controller is key unit of the model, its properties including the determinate, concentration, and mechanical contribute to the achievement of a specific architecture of computer system, such as the "stored-program" structure of von Neumann. But these characteristics also become the key constraints to the structure of system, it will be discussed in the rest of this paper.

### B. *Defects analysis*

We can derive three preconditions of "computable" from computability theory of the TM, three preconditions including: the problem must be formalized; must have an algorithm; must have a reasonable degree of complexity. It has led to discussion whether these preconditions can be broke[4].

In this paper, defects of the classical TM model are summarized as four aspects:

*1) TM is no suitable to expression computing capacity fundamentally*

A.M. Turing, in his paper, "On Computable Numbers, with an Application to the Entscheidungsproblem" [5], he put forward the theory model of automatic computer-the Turing machine when proving some mathematical problem is unsolvable, the reasoning are summarized as a series of simple mechanical action. It needs emphasizing that Turing proposition is focus on the weaknesses of mathematics, that is, what the TM can't do in solving math problems, such as undecidable for halting problem, and Turing himself also thought that the TM is not suitable for use as a general model to solve computational problems. But the computer industry gradually began to use TM as a model to illustrate the computability ability, then as a model to solve all computational problems, and magnify the role of the TM[6]. This may be the fundamental reason that the computer faces a series of difficulties later on.

*2) TM lacks of consideration in form*

The defects of TM model in form can be expressed as [7]: *a)* From the initial state of the string to the final state of string, it can be considered to be point-to-point mapping in defined space, and it does not resolve the uncertainty. *b)* Analog value is approximated to numerical value through clock frequency and the operation speed of the read and write header is determined, the degree of digitization is determined by the isogranular subdivision, as for whether this approximation is feasible or not, and how to the numerical value return to the analog value, it's not considered in the TM. *c)* The TM didn't consider formal methods of input and output, and human-computer interaction didn't appear in the process of computing.

*3) TM does not apply to parallel environment of multi-core*

The TM model and the von Neumann architecture is essentially a one-dimensional and serial structure[8], due to the multi-core processors which applied universally is essentially discrete and parallel structure, the TM model becomes theoretical issues that multi-core processors faced, it generates the problems such as: difficulties in parallel programming, speedup small in serial program and data consistency.

*4) Processing model of TM is inconsistent with human thinking[9]*

For the problem space of the described problem, the methods space is not consistent with the problem space in the solution that given by TM model, therefore there is a greater difference with thinking model of human[10], such as the traditional process-oriented design. With the extension of the scale of the problem, it causes the software crisis and promotes the study of the object-oriented approach.

### C. *Extension for classical TM model*

Aiming at the defects of classical TM, lots of research have tried to extend it from a different point of view, these extensions be divided into three categories in this paper:

*1) consider from perspective of input and output*

The classic TM model has a strong ability of converting, but it lacks of interaction with the external environment, the scholars including Turing and Milner who has got Turing Award try to use interactive machine (IM) to extend the TM model. The basic idea of interactive machine is: introducing the input and output actions which interact with the external environment and these acts are not under IM's control, the input stream elements are dynamically provided by an external mechanism that is not under its control[11]. The interaction machine model includes the persistent Turing machine, the timing interaction machine and the multi-band interactive machine, they have a stronger ability of description than the classic TM.

*2) consider from the process of transformation*

State transformation in TM model reflects a physical transformation in the electronic computer, but it can also achieve this transformation by means of biochemical means, such as the correlation characteristic of the DNA molecule[2]. The basic idea of the model of DNA computer is: firstly, encode with the DNA sequence, and then process DNA molecule with help of the DNA's characteristics of complementary binding and the action of the enzyme. Finally, read out the correct DNA sequence as an output by means of a specific approach. Compared to the classic TM model, the computer model of DNA has super ability of parallel computing and storage capacity for huge data.

*3) consider from the rules of transformation*

The classic TM model has only a single fixed state at a particular moment, but superposition and quantum coherence properties in quantum mechanics which can make the quantum have a variety of state at the same time at a particular point[12], the computation model that

implemented using this feature is an extension for the transformation rules of the classic TM model, so it has the natural ability for parallel computing.

### D. Summarization of TM characters

The classic TM model is extended from various point of view as above, it has proven that the computing ability of these models is superior to the classic TM, but there are some common characteristics which may be the factors restricting the further development of these models[6]. They can be summarized as the following aspects:

*1) These modes don't involve the complex system, they only describe the single interaction system.*

*2) They are local computation, input and output are mainly completed locally.*

*3) They have unified scheduling, they are running under the unified control of the scheduling algorithm.*

*4) Without human participation, they lack a key factor of the interference of human brain and human wisdom*

From these features, the high-performance computers with centralized control, the cluster computers, the virtual machines, and the distributed systems are still the specific form of the TM model. Looking for a computing model that can break through four limitation above, the classic TM model may be extended to a large extent. This paper attempts to discuss how to implement a specific extension in the context of the Internet operation mechanism.

## III. TM MODEL IN THE INTERNET ENVIRONMENT

### A. characters comparison of network model and TM model

The development of the Internet gradually change the computation mode, a new model of cluster computing, grid computing, and cloud computing appears under the promotion of the network. The salient features of the Internet is "focus on the interaction, there is no centralized and unified control", in essence, the internet is beyond the scope of the classical TM, so it's not a huge virtual TM. The differences between the operating mechanism of the Internet and the classic Turing computation are shown in table I [7].

As can be seen from the comparison of the characters, the Turing computation and the operating mechanism of the Internet have remarkably differences. Drawn from experience, individuals or stand-alone machine difficult to complete the task, but it can get better solution via Internet, so the operating mechanism of the Internet may provides effective reference to the extension of the TM model.

TABLE I. COMPARISON OF THE INTERNET AND TURING COMPUTATION

| Turing Computation | Operating mechanism of The Internet |
|---|---|
| Concern about the CPU and operating system | Concern about interaction between the nodes |
| Certain computation | Uncertain computation |
| Optimal solution | Best-effort solution |
| Unified scheduling | No centralized control, and no the dependence of the local preferences |
| Mechanical execution | Autonomous behavior |
| Computable model | Service model |
| Human do not participate in | Human actively participate in |

### B. Comparison of the state controller

The Internet can be seen as a huge computer, if we think the Internet also has a "internet finite state controller", then it should different with the finite state controller in TM. This paper attempts to discuss the internal mechanism of the two state controllers.

The characters of Turing finite state controller in that it gathers a variety of control in itself, it runs under the directions of the program, it overall coordinates the interaction with other components. The von Neumann architecture is a typical representative of this idea, the controller can be considered as a concrete manifestation of the Turing finite state controller. Its structure is shown in Figure 2.

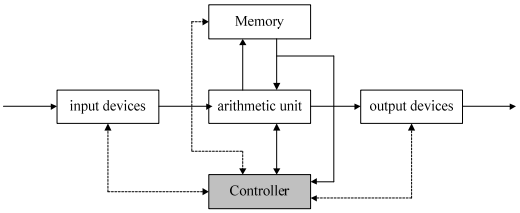


Figure 2. Centralized control structure

Compared to the features of centralized and unified scheduling, sequential, and certain input in the classic TM model, the computing on the Internet is focus on interaction, and the operational status of computer can be affected each other. It can be thought the state controller of Internet is distributed, as shown in Figure 3.

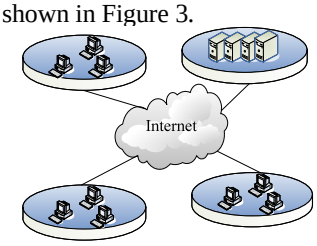


Figure 3. Distributed control structure

It's important to note that distributed control referred to here is different from the distributed systems. Although distributed systems are physically dispersed, but it still exists a unified control center to coordinate the various parts of the communication. Distributed control mentioned here emphasize that there is no unified control, and how the system running is difficult to describe, it depends on the interaction of the various parts. For distinguished from the classical TM model, this computation model with distributed control structure is called the network TM model in this paper.

### C. *Formal Description of the state controller*

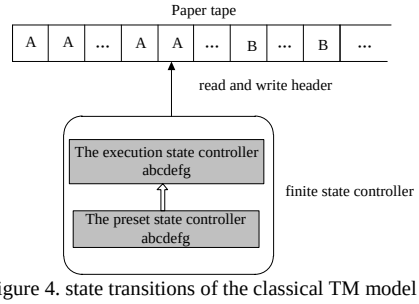


Figure 4. state transitions of the classical TM model

The biggest difference of the classical TM model and the network TM model is the internal structure of the state controller. Transformation rules of the state controller in classical TM are determinate and sequential, such as: the default state transition rules are “abcdefg”, and its state transition rules remains “abcdefg” in actual execution, as shown in Figure 4. However, there is no centralized and unified control in the network TM model, and its state transition rules is not determinate and sequential due to the introduction of interactive mechanism, for example: the default state transition rules are “abcdefg”, however the state transition rules may be “dafgecb” in actual execution, as shown in Figure 5. But how to achieve such a conversion is beyond the scope of this paper.

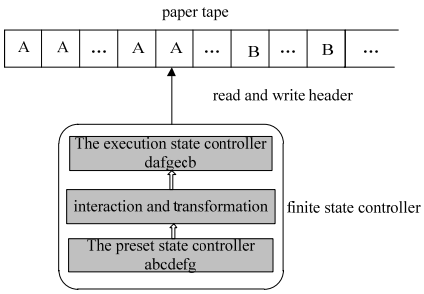


Figure 5. The state transitions of network TM model

## IV. THE ROLE OF VIRTUALIZATION ON NETWORK TM MODEL

The operating mechanism of network provides a reference for extending the classical TM model to the network TM model, the way how to use Internet resources is a key issue and virtualization can play a role thereinto.

Chris Langton, the father of artificial life, said that "the essence of the life is the organizational form of the substance, rather than the substance itself." Similarly, the essence of the Internet resources is the form of organization between information resources, rather than the TM by which the information is carried. It reflects three characteristics when users make use of the internet resources:

*1) Without caring about the manner of services for a specific application software.*

*2) Without caring about the physical configuration and management of the underlying resources of the computing platform and software environment.*

*3) Without caring about geographical position of the computing center.*

In general, it needs to provide a mechanism to shield the details, achieve dynamic configuration, and provide resources in terms of service, that is, the resources which the user used directly are virtual resources rather than physical resources. Virtualization provides a critical support for converting the physical resources into virtual resources. Virtualization technology[13, 14, 15] has become a trend in the development of computer technology, it provides a flexible method for division of hardware resources, it can form multiple isolated virtual partition through

abstracting, dividing, and configuring the actual hardware resources on a machine. This feature of virtualization can be used for the initial integration of Internet resources, its location in the entire network model is shown in Figure 6.

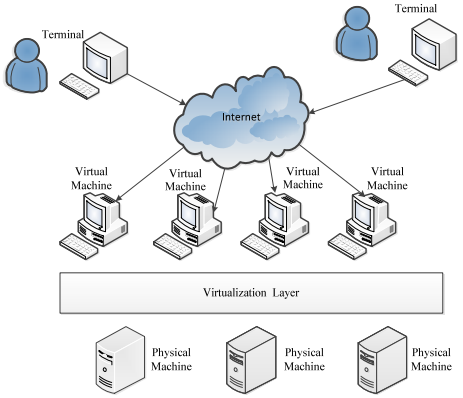


Figure 6 the location of virtualization in the network model

Although a single virtual machine is still a manifestation of the classical TM, however if the virtual machines are connected via the Internet, then the computing model will change radically. There are a variety of computing model based on virtualization and network, such as Open Nebula, Open Nebula, Nimbus, Eucalyptus, Amazon EC2, and Xenoserver etc.. The architecture of Open Nebula is shown in Figure 7[16], it not only has the operation to the computing process from the Internal users, but also has many interaction from External users in this model. The interaction between the users have a great deal of randomness due to without centralized and unified control, the state transition rules of the whole computing model no longer maintain certainty and order, so it has essentially difference compared with the determinate of state controller that in the classical TM.

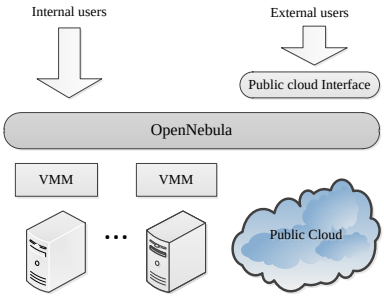


Figure 7 Architecture of OpenNebula

## V. CONCLUSIONS

The classic TM model has the features of serial computation, centralized control, process-oriented and so on, it has profound impact on the execution mode of the modern computer system, and also restricts the development of the computer to the direction of multicore parallel, quantum polymorphism. The combination of Internet and virtualization has produced a new type of computing model, which has many characters such as non-unified scheduling, interactive, and human involvement etc., these features are likely to be the entry point to extend the classic TM model, network computing based on virtualization offers a possible reference. Whether it can break through the classic TM model and form a new computing model using the virtualized computing is the focus of this paper in the future.

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