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CYBERNETICS BASED ON HUMAN CONTROL THINKING

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Abstract. *Wiener's cybernetics is a scientific theory based on the communication mechanism in animals and machines. Up to now, the current control theories can be divided into two kinds: traditional control theory and intelligent control theory. The traditional control theory is also divided into classical control theory and modern control theory. The controller designed according to the current control theory still has some disadvantages; therefore, we must learn from the human control wisdom and seek the new control theory. The cybernetics based on human control thing is called Human-Thinking Simulated Control theory, which reveals the control thinking mechanism and control wisdom of human brain. The theory can be simulated and realized by a computer to overcome the disadvantages of current control theory in application. Human-Thinking Simulated Control theory is innovative and has achieved important research results and applied results.*
Keywords: Intelligent control, Control thinking, Human-Thinking Simulated Control, Level control

1. **Introduction.** Watt invented a hammer-type centrifugal governor, which made the steam-powered system speed controllable, leading to the first industrial revolution. In order to study the control stability and design of steam-driven system, Maxwell set up the mathematical model of the system from the mathematical point of view for the first time, and opened the prelude to the birth of classical control theory. Subsequently, Russian mechanic Вишнеградки, British mathematician Ruth, German mathematician Huervitz and Russian mathematician Liaponov contributed to the development of classical control theory. In 1945, American mathematician Wiener extended the concept of feedback to all control systems. In 1948, Wiener published cybernetics [1], which laid a foundation for cybernetics and marked the formal appearance of cybernetics as an independent discipline.

With the rapid development of space technology in the late 1950s, the optimal control problem of multivariable systems is urgently needed to be solved. Many scholars tried to extend the classical control theory to the control of multivariable systems, but they failed. Therefore, it is necessary to seek new theories and methods, so the birth of modern control theory. The main scholars who have contributed to the modern control theory are the Soviet mathematician Pontryagin, the American mathematician Kalman, the professor of Manchester University of England RosenBrock and so on.

We can call the classical control theory and the modern control theory as the traditional control theory. Their common characteristic is that the research problem depends on the mathematical model of the system, namely the known dynamic equation or the equation of state of the system. Classical control theory mainly deals with single-input, single-output, steady and linear systems. Modern control theory focuses on multi-input, multi-output,

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steady or time-varying, linear or nonlinear systems. For some complex control systems, the mathematical model is difficult to be established. Even if the model is established, there are many hypothetical conditions.

Since the traditional control theory has some shortcomings in solving the complex system control problem, from the early 1970s, intelligent control theory has emerged from the intersection of artificial intelligence technology and control theory. The main scholars who contribute to the intelligent control theory are Fu and Waltz [2,3], Saridis et al. [4,5], Zadeh [6] and so on. Intelligent control is the advanced stage of the development of traditional control, which is produced under the background of solving the high complexity, high uncertainty and higher control performance of the controlled system.

Whether it is the traditional control theory based on the system model or the intelligent control theory without the system model, there are some disadvantages as follows.

From the viewpoint of control algorithm, a controller designed by the above theories is mostly based on the error and error change. Actually, the variation of a controlled variable can be described by the following characteristic concepts as changing magnitude, changing direction, changing tendency and changing velocity. The error and error change just reflects the changing magnitude of the controlled variable, and the changing direction, changing tendency and changing velocity cannot be shown in the controller algorithm. On the other hand, if the error exists, the controller output exists. If the controller output exists, the actuator in a control system must work. So the service life of the actuator will be reduced, and the oscillation of the controlled variable is unavoidable at the same time. Because only is the error zero, the controller output would remain unchanged and the actuator would not act. However, it is impossible that the error would be zero in a continuous control system.

From the viewpoint of controller design, the controller designed by the traditional control theories must depend on mathematical model. If the mathematical model of a control system cannot be built, the controller cannot be designed. If the mathematical model is not correct, the controller will not work well. Although intelligent control does not need plant mathematical model, there are also many parameters which should be decided. Sometimes the parameters are difficult to be modified.

From the viewpoint of control strategy, there are some following control strategies such as feedback control, feed-forward plus feedback control, cascade control, and feed-forward plus cascade control. The characteristic of the above control strategies is closed-loop control, so there is no switch between closed-loop and open-loop control. Figure 1 shows one of control strategies, which is closed-loop feedback control. A major advantage of the feedback control is that by placing a "feedback loop" around a system which initially has quite unsatisfactory performance characteristics, one can in many cases construct a

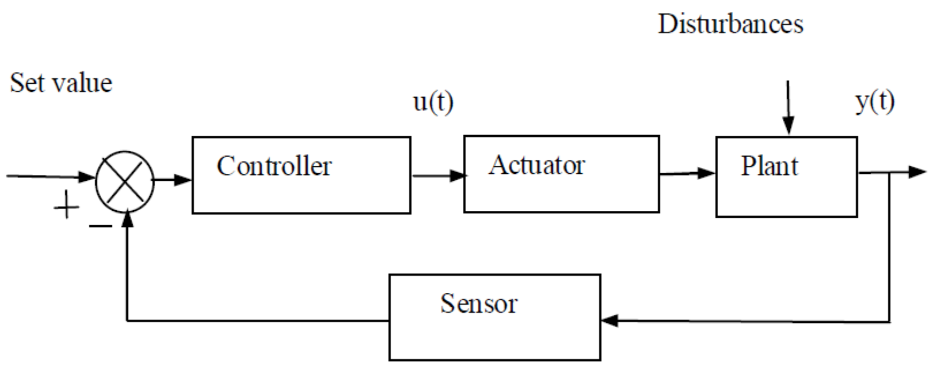

FIGURE 1. Closed-loop feedback control

system with satisfaction. The control $u(t)$ is modified in some way by information about the behaviour of the system output. A feedback system is often better able to cope with unexpected disturbances and uncertainties about the systems dynamic behaviour. However, it need not be true that closed-loop control is always superior to open-loop control.

From the viewpoint of control process, the sampling period and controlling period are fixed. Even though the controlled variable arrives at the desired value and is stable, the controller always works step by step.

By the simulation, it can be found that the step response of the control system is a dynamic response process. Qualitative control performances are generally measured by stability, speediness and accuracy. Figure 2 shows the test result of the traditional control strategy [7]. From the viewpoint of control performance, it is obvious that overshoot and oscillation are unavoidable. When the controlled variable is stable, the controller outputs continuously and the actuator always acts.

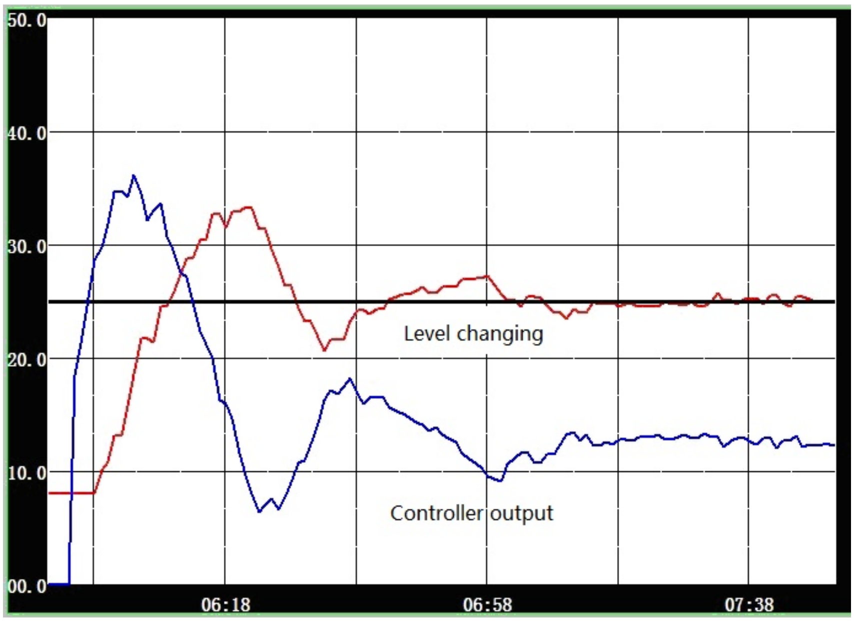

Figure 2. Test result of closed-loop feedback control

According to the above analysis, the control process based on current control theories is lack of intelligence and flexibility, so the harmony, uniformity, and coordination of control performances among stability, speediness and accuracy cannot be solved. In general, if the dynamic response is fast, the overshoot is bigger and the adjusting time is longer.

To overcome above shortcomings, we must learn from human control wisdom. In fact, the human brain is the best controller in the world. The automation system liberates the person, but it cannot learn human control wisdom from the control strategy and the method well. When people ride bicycles, drive cars, perform acrobatics and other complex devices, equipment, and systems, they do not need mathematical models or complex control algorithms, but they can control them very well. It can solve the contradiction of control performances among stability, speediness and accuracy.

After many years research, we have put forward the control theory and method based on human control thinking, which is called Human-Thinking Simulated Control theory [7]. Many important research results and application results have been obtained, and a new direction of intelligent control theory research has been opened up. It is original and innovative.

Due to the limitation of the space of the paper, the paper focuses on the basic concepts, theoretical framework, research results and application fields involved in the research of Human-Thinking Simulated Control. Through the introduction of this paper, readers can accurately understand the research purpose, significance and innovation of Human-Thinking Simulated Control. The paper provides reference for scholars who want to engage in Human-Thinking Simulated Control research. The results of the previous research on human-like thinking control can be found in the relevant papers published by the author. The paper is organized as follows. In Section 2, we briefly explain the concepts of human general thinking, control thinking and their computer realization. In Section 3, human control wisdom and intelligence is discussed. In Section 4, theoretical structure of Human-Thinking Simulated Control is introduced. In Section 5, advantages and test results of cybernetics based on human control thinking are shown. In Section 6, we show application fields and plants of Human-Thinking Simulated Control. Section 7 is devoted to a summary.

2. Human General Thinking, Control Thinking and Computer Realization.

2.1. **Human general thinking.** Different scholars have different opinions on the study of human thinking. We think that Professor Qian Xuesen, a famous scientist, is more scientific in the division of human thinking, that is, human thinking is divided into three forms: image thinking, abstract thinking and inspiration thinking [8].

Image thinking, also known as image intuitive thinking or image intuitive reasoning thinking, is based on perceptual knowledge and concept thinking, and it is subjective. The language of the human brain is not the language of mathematics, and the human brain is mainly based on the concept of thinking. In people's life, most of the thinking is image intuitive reasoning thinking. From the reasoning premise and conclusion, premise and conclusion are qualitative knowledge. Abstract thinking, also known as abstract logical thinking or abstract logical inference thinking, is based on scientific knowledge, formulas and theorems, and it is objectivity. From reasoning premise and conclusion, they are scientific quantitative knowledge. Inspiration thinking, also known as epiphany thinking, is a high-level fusion of two kinds of thinking, and it is easy to produce significant discoveries and inventions.

When one is born, the image intuitive thinking occupies a dominant position. With the increase of knowledge and the improvement of cognitive ability, the thinking ability of abstract logical thinking is gradually enhanced, although the image intuitive thinking still occupies a dominant position in daily life. However, in the work and learning life, abstract logical thinking ability began to occupy a dominant position. Inspirational thinking is often found in scientific research and occasionally in life.

For human general thinking, we believe that image intuitive thinking is low-level thinking, and abstract logical reasoning thinking is high-level thinking and inspiration thinking is the highest level thinking. Of course, for the specific human thinking process, image intuitive thinking and abstract logical thinking are complementary and mutual integration, and the division of primary and secondary is relative.

2.2. **Human control thinking.** Human control thinking is formed on the basis of general thinking, and it has a specific role of thinking. As above discussed, in the control process such as riding bicycles, driving a car, and performing acrobatics, people have no control experience at first, so they need to use simple calculation and analysis to exert control actions, and abstract logical thinking occupies a dominant position. After he has a lot of training and learning and accumulates a large number of control experience and skills, image intuitive thinking gradually becomes the main control thinking. In the process of manual control, there is no thinking time in some unexpected situations, which reflects the advanced control wisdom of human beings and can be regarded as the inspiration thinking. Obviously, the inspiration thinking is also based on control skills.

From the viewpoint of control thinking, the following conclusions are drawn: 1) human control thinking is also divided into three kinds: image intuitive reasoning control thinking, abstract logical inference control thinking and inspiration control thinking; 2) image intuitive reasoning control thinking is control thinking based on control experience and skill, and abstract logical inference control thinking is control thinking based on calculation and inspiration control thinking is the most advanced image intuition reasoning control thinking. The inspiration control thinking can be regarded as "no thinking intelligence"; 3) it is contrary to human general thinking that abstract logical inference control thinking is low-level thinking and image intuitive reasoning control thinking is high-level thinking; 4) manual control does not require mathematical model or complex algorithm, because the human brain cannot realize the complex algorithm, so the abstract logical inference control thinking can only realize the simple control algorithm; 5) in the artificial control process, the abstract logical inference control thinking plays a leading role at the initial stage. With the accumulation of control experience, the image intuitive reasoning control thinking gradually plays a leading role in control; 6) the mining of control experience and skill in the process of control is very important, which is the basis to realize the image intuitive reasoning control thinking.

2.3. **Computer realization.** Characteristics of a computer control system are that the input is quantitative data and the output is also quantitative data. It is easy to use computer to realize the abstract logical inference control thinking. To realize the image intuitive reasoning control thinking, we need to do the following transformation: 1) convert the data space into the concept space; 2) based on the qualitative concept and the control rules formed by the control experience, the output qualitative concept is obtained; 3) the output qualitative concept is transformed into the output quantitative data.

Figure 3 shows the inference process of image intuitive reasoning control thinking [7].

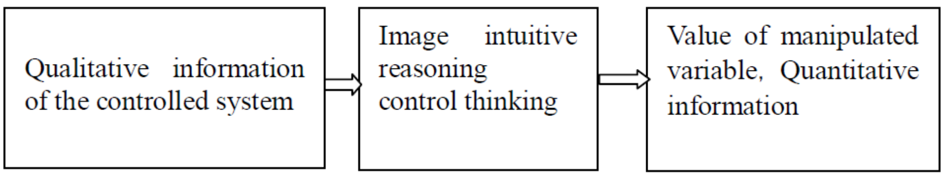

FIGURE 3. Image intuitive reasoning control thinking

As shown in Figure 3, the input is qualitative information and the output is quantitative information. Image intuitive reasoning control thinking depends on qualitative concepts and control experience and skills.

Figure 4 shows the inference process of abstract logical inference control thinking [7].

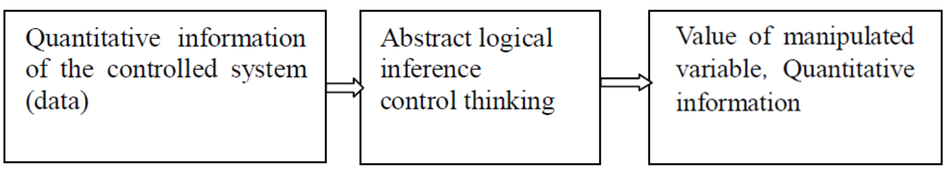

FIGURE 4. Abstract logical inference control thinking

As shown in Figure 4, both the input and the output consist of quantitative information. Abstract logical inference control thinking depends on quantitative data and a simple control algorithm, because the human brain cannot realize a complex algorithm.

3. **Human Control Wisdom and Intelligence.** A human brain controller is a very complex, perfect, self-learning, self-organizing and adaptive controller. The human senses of sight, hearing, smell, taste and touch are similar to the physical sensors in a control system; they obtain information including controlled variables information and disturbance variables information. The information is used by the human brain, and a controlling action is performed via the control system by human hands and feet to obtain the desired goal. The characteristics of human control intelligence are summarized as follows.

1) Depending on control experiences. A man can ride a bicycle very well without a mathematical model, and he can also drive a car well without a mathematical model. Some acrobats can cooperate with each other well to perform some complex actions, and they do not need a mathematical model and complex algorithms. Both the driver and acrobat can control the plant by the control experiences and skills.

2) Depending on the combination of image intuitive reasoning control thinking and abstract logical inference control thinking.

3) Using different control methods in different stages. When a man controls a plant, he does not have any control experiences. The control process can be divided into three stages, as shown in Figure 5.

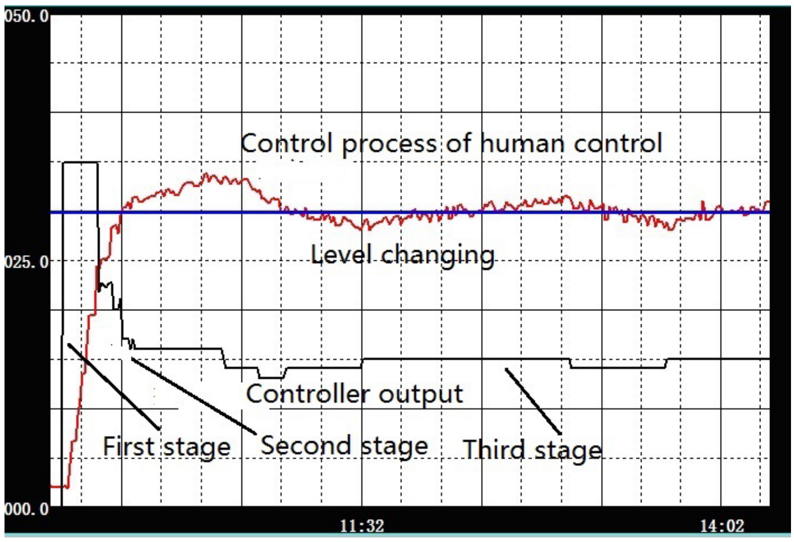

Figure 5. Process of Human-Thinking Simulated Control

The first stage is referred to as the stage of fast control. In the first stage, an experienced control expert can use the maximum output of a manipulated variable to obtain a fast dynamic response. While the controlled variable moves toward the set value, the output of the manipulated variable will gradually decrease. The abstract logical inference control thinking has an important role in this stage. When the controlled variable arrives at the set value, the first stage ends.

The second stage is referred to as the stage of adjusting and learning. According to the changing magnitude, changing direction, changing tendency and changing velocity of the controlled variable, the operator will not stop controlling until the controlled variable satisfies the controlled accuracy and is stable. If the following conditions are satisfied, the second stage ends:

$$|e| \leq \varepsilon \text{ or } |\Delta e| \approx 0 \text{ or } e = 0$$

where e is the difference between the set-point and the output variable, and ε is the controlled accuracy.

In the second stage, additional control experiences and skills are mined and stored. The image intuitive reasoning control thinking and abstract logical inference control thinking will occur in this stage. "Learning" indicates that the control experiences and skills can be mined and modified in the process.

The third stage is referred to as the stage of coping with disturbances. The operator will obtain additional control experiences and skills in the second stage, and he will become a control expert. When he is a control expert, he understands the control system well. He knows how to control the system when the disturbances appear. His controlling action depends on his control experiences and skills; thus, this stage is the most advanced stage and is referred to as the image intuitive reasoning control stage. Image intuitive reasoning control thinking has an important role in this stage.

4) Switching between open-loop control and closed-loop control. As an experienced control expert controls a system, whether the present value of the controlled variable is equal to the desired value should be cared and observed first. If the controlled variable arrives at the desired value, the stability should be concerned. If the controlled variable does not achieve an objective, the closed-loop control will continue until the controlled variable arrives at the control accuracy. If the controlled variable arrives at the control accuracy and is instable, the closed-loop control is also used until it is stable. If the present value of the controlled variable is not equal to the desired value, the closed-loop control plays an important role. If the controlled variable arrives at the control accuracy and is stable, the closed-loop control will switch to open-loop control. At the time, the controller is sampling the present value of the controlled variable, waiting and observing whether the controlled variable leaves from the desired value. If the controlled variable leaves from the desired value, the open-loop control will switch to closed-loop control again.

5) Varied sampling period and controlling period. One of the best advantages of the human control thinking is that the sampling period and controlling period are changing in the control process. If the controlled variable is stable relatively, the control strategy of waiting, watching and regulating is taken. So the open-loop control works at the time, and the sampling period and controlling period may be longer than that in the closed-loop control process.

6) Depending on dynamic performance of the controlled variable and disturbance [9]. If the manipulated variable remains unchanged, the controlled variable remains stable in open-loop control state. And then a disturbance emerges suddenly and disappears after a time, the controlled variable will change forward to the following occasions as dispersion, oscillation, relative convergence and absolute convergence. Dispersion characteristic means that the controlled variable leaves the desired value and goes forward with increasing tendency or decreasing tendency. Oscillation characteristic means that the controlled variable changes as an oscillation around the desired value. Relative convergence characteristic means that the controlled variable leaves the desired value at the first, and then it remains stable at a new state. Absolute convergence characteristic means that the controlled variable leaves the desired value at the first, and then it goes back to the desired value. If the controlled variable has convergence characteristics, the switching of close-open loop control can be taken as the control strategy in order to cope with disturbances. If the controlled variable has dispersion characteristics and oscillation characteristics, only is the closed-loop control taken in order to cope with disturbances.

On the other hand, the dynamic performance of a disturbance is also very important for the control strategy. If the disturbances are constant disturbances, the controller should output and realize feed-forward control according to the previous control experiences as soon as the disturbances are measured. If the disturbances are transient disturbances, the controller can wait and observe the change of the controlled variable for a while. If the controlled variable can return to the previous value, the controller can remain unchanged. If the disturbances are time-variant and random, the close-loop control should be used.

In fact, all control theories and technologies come from human control thinking and control intelligence [10]. Automatic control technology begins from simulation of human control actions, and automatic control theory based on feed back theory originates from manual control simulation. Professor Astrom et al. [11] pointed out that cybernetics was founded by Wiener based on the study of communication and control of animal and machine, and many concepts were defined. Now some new control concepts should be defined and discussed in the control field. He also said that human image intuitive reasoning control thinking plays an important role in the industry controller design. Another famous scholar Saridis et al. [4,5] pointed out that the only royal road was to learn from human brain in the paper of knowledge, implementation, structure of intelligent control system.

For example, PID method is the most popular control method. As we know, PID is not the product of theoretical research, but it comes from the practice and summary. PID is the liner combination of proportion integration and differentiation. Proportion control represents the present, and integration control represents the past and differentiation control represents the future. When we think problems and solve problems, we also analyze the combination of the present, the past and the future. So PID is similar to human thinking process. From the control thinking, proportion control stands for human imagination zoom thinking, and integration control stands for human accumulation thinking and differentiation control stands for human forecast thinking. It is the reason why PID can be used forever in many fields because PID represents human control intelligence. Of course, PID is only a combination of specific thinking intelligence (imagination, memory, prediction), which does not represent all the control wisdom of human beings. Human-Thinking Simulated Control comprehensively studies the control thinking and control wisdom of human beings, and forms a unique theoretical system and method.

4. **Theoretical Structure of Human-Thinking Simulated Control.** Based on the above characteristics of human control intelligence, a new control theory which is called Human-Thinking Simulated Control is pointed out by the author. The academic monographs called human-thinking simulated intelligent control [7] is published. Human-Thinking Simulated Control is based on human cognition and human control thinking mechanism. The biggest characteristic of Human-Thinking Simulated Control is to study the image intuitive reasoning control thinking, the abstract logical inference control thinking, the formation mechanism of human brain control experience and skills and the controller structure simulating human control thinking. Human-Thinking Simulated Control does not need complex control algorithm and plant mathematical model. The study of Human-Thinking Simulated Control extends research direction for intelligent control. Human-Thinking Simulated Control is a new branch of intelligent control, which is creative and innovative.

Figure 6 shows the theoretical structure of Human-Thinking Simulated Control (HTSC), which includes three parts: Human-Thinking Simulated Control for SISO control system, Human-Thinking Simulated Control for MIMO control system and human body simulated intelligent distributed control system. Each part also includes some main research contents. HTSC for SISO is the foundation for the study of HTSC for MIMO. Human

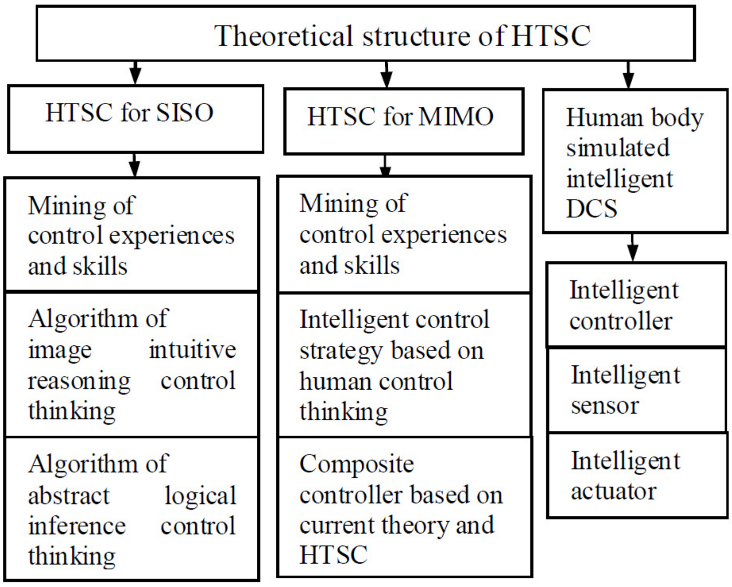

Figure 6. Contents of theory of HTSC

body simulated intelligent DCS is the application study based on HTSC for SISO and HTSC for MIMO.

It is easier for a man to control SISO system, so it is also easier to study SISO control system based on HTSC. Up to now, we built the models of the image intuitive reasoning control thinking and the abstract logical inference control thinking, and we designed the method of how to mine control experiences and skills and how to use it in the real control process. The structure of Human-Thinking Simulated Controller for SISO control system has been also built.

MIMO control system is mostly a complex system, and it has many controlled variables, manipulated variables and disturbance variables. A complex system is always time delays, large time constants, uncertainties, nonlinearities, and model-free system. So control based on human control thinking for MIMO control system is more difficult than that of SISO control system. We use different methods for studying MIMO control system based on HTSC. Intelligent control strategy based on human control thinking and composite control strategy based on human control thinking have been pointed out. The method of mining the control experiences and skills for MIMO control system is also different from the method for SISO control system.

Based on the study of the HTSC for SISO control system and HTSC for MIMO control system, a new process control method which is called human body simulated intelligent Distributed Control System (DCS) has been pointed out. As we know, a control system needs a better control method, and it also needs a better control system structure. A normal person not only has better thinking intelligence, but also has a better body communication structure. Control method simulates human thinking intelligence, so control system structure can also simulate body communication structure. It is also the application study for the HTSC for SISO control system and HTSC for MIMO control system.

The intelligent controller, intelligent sensor and intelligent actuator in Figure 6 differ from other intelligent instruments. The intelligent controller is the integration of human thinking intelligence, the intelligent sensor is based on the human visual intelligence and the intelligent actuator is based on human kinesthetic intelligence.

The main research results are as follows: 1) the transformation method from data space to concept space is proposed, and the related concepts including controlled variable, manipulated variable, disturbance variable, stability and control process are defined [12]; 2) the three control algorithms are proposed to simulate the abstract logical inference control thinking [13]; 3) the algorithm of simulating image intuitive reasoning control thinking is proposed [14]; 4) the algorithm of mining and calling control experience is proposed for SISO system and MIMO system [15]; 5) the controller structure of HTSC is proposed for SISO system and has been verified in the actual control system [7]; 6) the compound control strategy based on HTSC for complex systems is proposed [9]; 7) the architecture of human body simulated intelligent distributed control system is proposed [16]. At present, the research of HTSC based on the big data technology is being carried out. By using a large amount of data information generated in real-time control process, and with the help of big data processing technology, the control experience and skills are excavated. The theory of HTSC will be perfected by big data technology.

The general structure of Human-Thinking Simulated Control is shown in Figure 7. The controller is designed according to the characteristics of human control intelligence and the human body communication mechanism.

From the viewpoint of human control intelligence, the controller includes the following function blocks: concept space, abstract logical inference, image intuitive reasoning, control experiences mining, stage identification and closed-open loop switch. The control experiences mining function also includes rule correction, rule decision, rule database, history database and man-computer interaction functions.

From the viewpoint of the human body communication mechanism, the controller includes the following function blocks: intelligent controller object, soft sensor object and soft actuator object. The intelligent controller object includes the functions of human control intelligence, which is similar to the human brain. In a manual control system, the human ear and eye have the role of sensor, and the human hand and leg have the

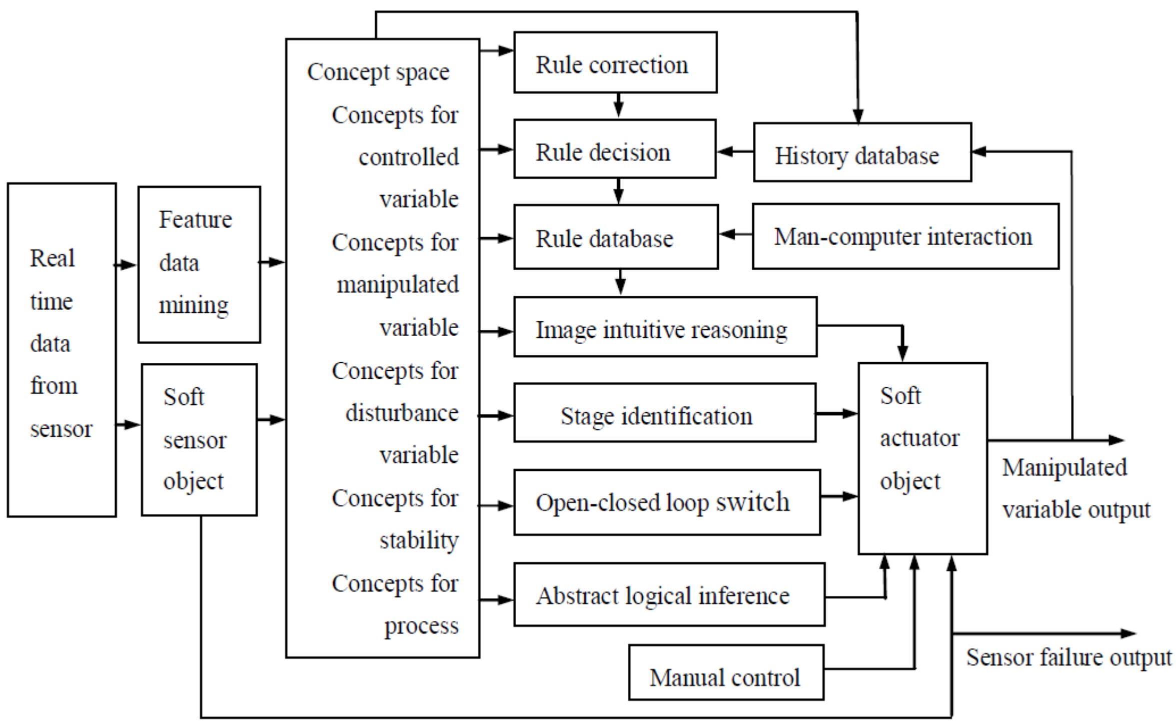

Figure 7. Structure of Human-Thinking Simulated Controller

role of actuator. The human brain is an intelligent controller; however, the human ear, eye, hand and leg also have local intelligence. Maybe local intelligent controllers exist in the human ear, eye, hand and leg. Thus, the soft sensor object is designed according to the local intelligence of the human eye and ear, and the soft actuator object is designed according to the local intelligence of the human hand and leg. The three intelligent objects cooperate with each other to maintain a control system with safety and reliability. The design and implementation of the soft sensor object and the soft actuator object are discussed in [17,18].

In Figure 7, the output of manual control has the highest priority. If it works, the soft actuator object chooses its output to a real physical actuator. The output of image intuitive reasoning control and abstract logical inference control has a higher priority. The soft actuator object chose one of these outputs as output to a real physical actuator based on the stage identification result. In the first stage, control experience and skills are lacking; thus, abstract logical inference control has a main role in the control. Simultaneously, control experience and skills are produced. In the adjustment stage, image intuitive reasoning control begins to have a role while control experience and skills can be changed, mined and modified. In the last stage, image intuitive reasoning control has a main role with affluent control experience and skills. These control processes simulate the human manual control process. Due to the space constraints of the paper, the main components in Figure 7 are highlighted as follows.

4.1. **Concept space.** Human language is not a kind of mathematical language, and concepts are the tool of human thinking. As we discussed, the image intuitive reasoning control thinking depends on qualitative concepts and control experiences and skills. However, for a computer control system, the input and output are real-time data. If we use a computer to simulate the image intuitive reasoning control thinking, the following steps should be done. 1) We should define some concepts previously by data information, and then these concepts can be mined from the real-time data in a control system. So the convert from quantitative information to qualitative information will be realized. 2) We also should make inference rule database formed by some simple control rules at first, and the inference rules can be improved and enriched in the controlling process. The rule is kind of IF-THEN rule, and the inference base is the concepts. For example, IF the error of a controlled variable is bigger THEN the output of the controller is bigger. 3) The concepts related to controller output (for example, bigger) should be converted to the quantitative data (voltage or current), because an actuator only accepts quantitative data (voltage or current). So in order to realize HTSC by a computer, some concepts related to controlled variable, controller output, disturbance variable, stability and controlling process are defined, which form the concept space. The detailed discussion is in [12].

4.2. **Algorithms of abstract logical inference control.** As we discussed, abstract logical inference control thinking depends on simple control algorithms, because human brain cannot realize complex algorithms. In [19], three algorithms of simulating abstract logical inference control thinking are introduced. One is the three-stage control algorithm, one is the increase-decrease plus bisection control algorithm and the other is the four parameters control algorithm.

The three-stage control algorithm means that it includes three stages which are initial stage, adjusting and learning stage and dealing with disturbance stage, and each stage uses different control algorithms.

The increase-decrease plus bisection control algorithm comes from the following philosophy of daily life. When we heat a bottle of milk by a microwave oven with two minutes at first, it may be hotter. At the next time, we heat it with one minute, and it may be cool. So at the next time, we heat it with one and a half minutes, and it will have appropriate temperature for drinking. For a manual control, an expert always uses this kind of thinking to regulate the controlled variable.

As the above discussions, the current control methods just depend on the changing magnitude (error and error change) of the controlled variable, but human control can depend on the changing magnitude, the changing tendency, the changing speed and the changing direction of the controlled variable. An expert can control the controlled variable according to the above four parameters, and the parameters form the state space of the controlled variable. Based on the four characteristic variables, the output of manipulated variable can be decided. The method is called four parameters control algorithm. The test proves that the effect of eliminating disturbances is better and the switch of closed-open loop control is realized, so the four parameters control method simulates human control thinking very well. The method overcomes disadvantages of traditional control methods which depend on the error and the error change only.

4.3. **Algorithm of image intuitive reasoning control.** In order to understand the image intuitive reasoning control, let us compare it to fuzzy control. Their common features are the following. 1) Both of them simulate human control thinking, and they are very simple conceptually. They consist of an input stage, an inference stage and an output stage. At the inference stage, they depend on the IF-THEN rule-based inference. 2) At the input stage, there is the processing of converting a crisp input value to concept variable value. 3) At the output stage, they should give a specific crisp value to the actuator.

Their different features are the following. 1) Fuzzy control converts the crisp input value to logical variables that take on continuous values between 0 and 1, and the process is called fuzzification by membership functions. The image intuitive reasoning control converts the crisp input value to the characteristic variable value (X_1, X_2, X_3 and X_4). 2) For the fuzzy control, the inference stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value, which is called defuzzification. For the image intuitive reasoning control, the inference stage only selects one of rules, and the specific control output values are gotten directly by the rule. So the image intuitive reasoning control simulates human control thinking completely, because human brain cannot realize complex algorithm such as the "max-min" inference method of fuzzy control. 3) Fuzzy control depends on a collection of logic rules in the form of IF-THEN statements, and these IF-THEN statements should be determined firstly according to manual control experiences. The fuzzy controller could not be designed without previous control experiences, and the IF-THEN statements are also not changed as soon as the controller has been designed. Although the image intuitive reasoning control also depends on IF-THEN rules, most of the rules are mined in the real control process. As discussed earlier, a few of rules are determined at the first stage, and then the rule database will be enriched at the second stage and the last stage. The image intuitive reasoning control plays main role at the last stage.

[14] introduces the algorithm of the image intuitive reasoning control in detail.

4.4. **Open-closed loop switch.** Open-closed loop switch is also important for maintaining a stable control system. In the open-loop control process, the controller output remains the same as previous output, but the controller continues to sample data and perform some analysis. The switch is performed by depending on the state analysis. Figure 8 shows the process of switching between open-loop control and closed-loop control.

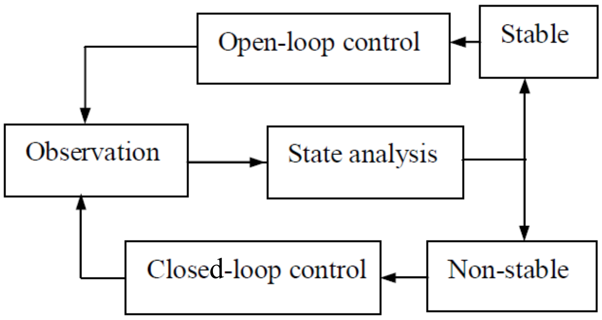

Figure 8. Open-closed loop control switch

5. **Advantages of Cybernetics Based on Human Control Thinking.** Compared with current control methods, such as PID, adaptive control, optimal control, and fuzzy control, Human-Thinking Simulated Control has the following advantages and characteristics.

From the viewpoint of the control process, the control process of HTSC includes three stages: the initial stage (first stage), the stage of adjusting and learning (second stage) and the stage of coping with disturbances (third stage). The different stages use different control algorithms, and a switch between closed-loop control and open-loop control occurs in the control process.

From the viewpoint of the control mechanism, HTSC is based on human cognition and the human control thinking mechanism. Abstract logical inference control plays an important role at the first stage of human control process, because there are no any control experiences and skills. With the collection of control experiences and control workmanships, image intuitive reasoning control will play an important role later. So image intuitive reasoning control is regarded as more advanced than abstract logical inference control in human control thinking process. The above two inference control methods combine together to realize a complex system control.

From the viewpoint of the control algorithm, HTSC depends not only on the error and error change but also the identification of characteristics variables that correspond to the changing magnitude, direction, velocity and tendency of the controlled variable, the dynamics features of the controlled variable, disturbance variables and manipulated variables, and the relationships among the controlled variable, disturbance variables and manipulated variables, the manual control experiences and strategies.

From the viewpoint of control system safety, intelligent communication occurs among the intelligent soft sensor object, intelligent soft actuator object and intelligent controller object. If one of these objects did not function, its functions could be replaced by other objects. Thus, the three objects can cooperate with each other to eliminate some special failures of the control system.

From the viewpoint of the control system structure, a human body simulated intelligent DCS has the same functions as the general DCS and FCS. However, the new control system has special functions with fault diagnosis and treatment. The new control system integrates human thinking intelligence, visual intelligence and kinesthetic intelligence and it can maintain the safety and reliability of the controlled system.

From the viewpoint of control performances, the harmony, uniformity, and coordination of control performances among the stability, speediness and accuracy are solved by Human-Thinking Simulated Control.

Based on the controller in Figure 7, some of the test results for a level control system are shown in Figure 9, Figure 10, Figure 11, Figure 12, Figure 13 and Figure 14. Figure 9 and Figure 11 show the first stage and the second stage. Figure 10 and Figure 12 show the last stage. Figure 13 and Figure 14 show the effect of coping with disturbances by HTSC. Compared to Figure 2, the effectiveness and advantages of the test are summarized as follows.

1) The three-stage control is realized. The dynamic response is fast, and there is almost no overshoot and the adjustment time is short. As the above discussed, the step response of the current control method has contradictions among the stability, speed and accuracy. The Human-Thinking Simulated Control solves the above contradictions very well.

2) The switch between open-loop control and closed-loop control is realized, which is one of the important characteristics of the Human-Thinking Simulated Control. When the controlled variable meets the given control requirements, the system changes to open-loop control. At the same time, the manipulated variable remains unchanged. The control

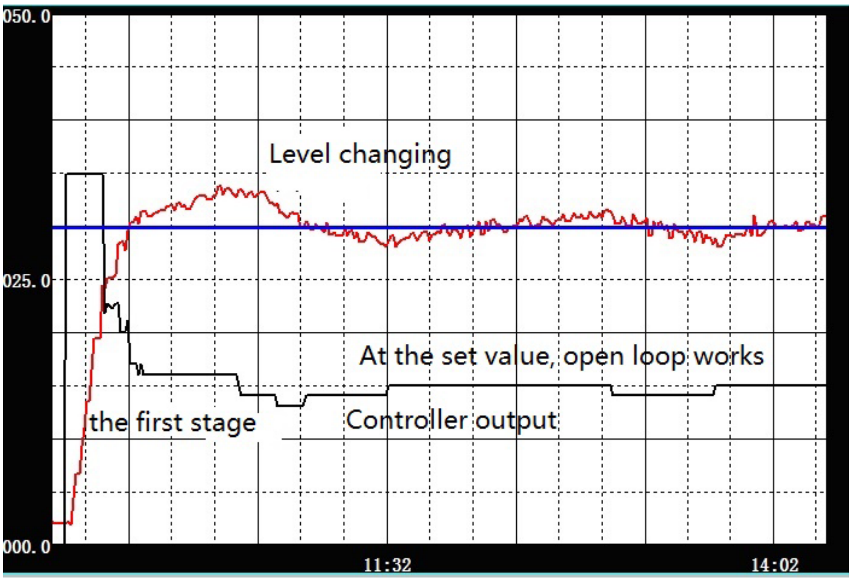

Figure 9. Test curve of level control

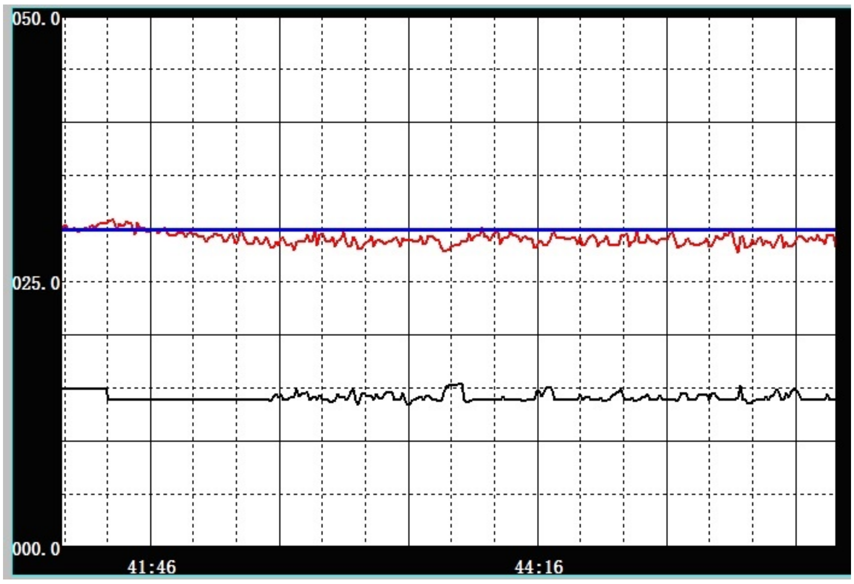

Figure 10. Test result of the last stage

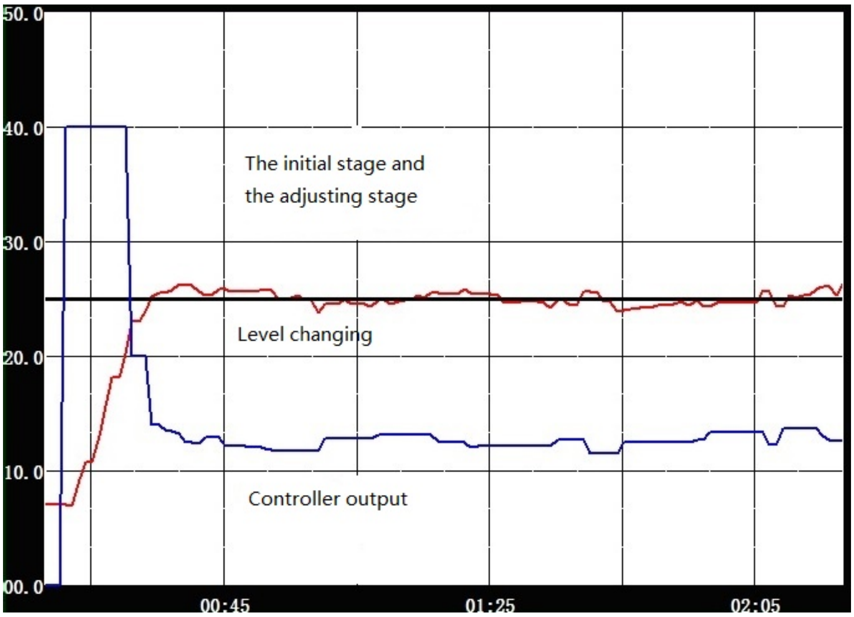

Figure 11. The initial stage and the adjusting stage

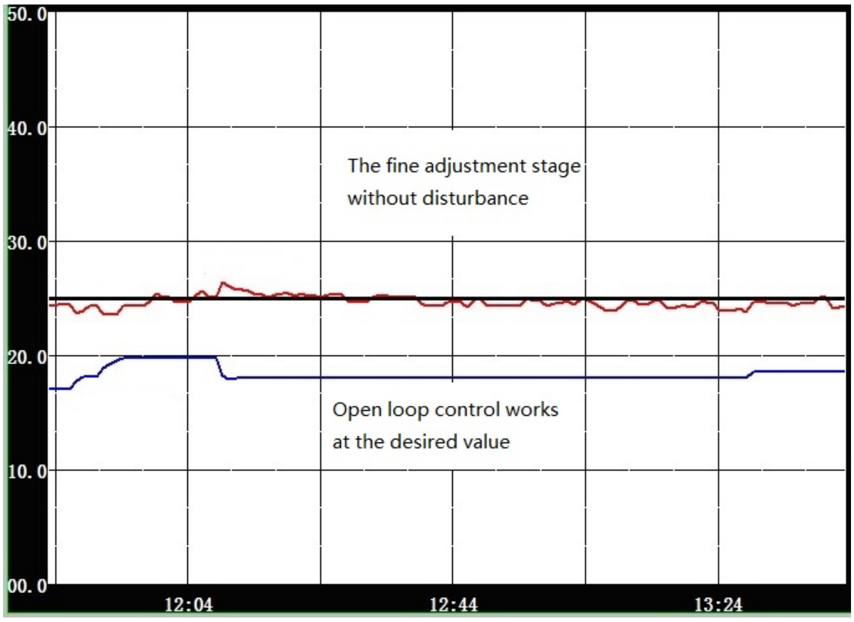

Figure 12. The last adjustment stage

strategy of waiting a while, taking a look and adjusting is used. In the open-loop control stage, the actuator does not act, which can effectively prolong the life of the actuator.

If a disturbance suddenly appears, the controller can overcome it rapidly and keep the controlled variable into a stable state as shown in Figure 13 and Figure 14. The overshoot is minimal, and the switch of closed-open loop control according to the controlled variable states and the variable sampling period in the control process are employed in the system.

6. **Application Fields and Plants of HTSC.** Human-Thinking Simulated Control has extensive applications in the following fields and plants.

1) A multi-input and multi-output control system, for example, the temperature, humidity and oxygen content control in the incubation process.

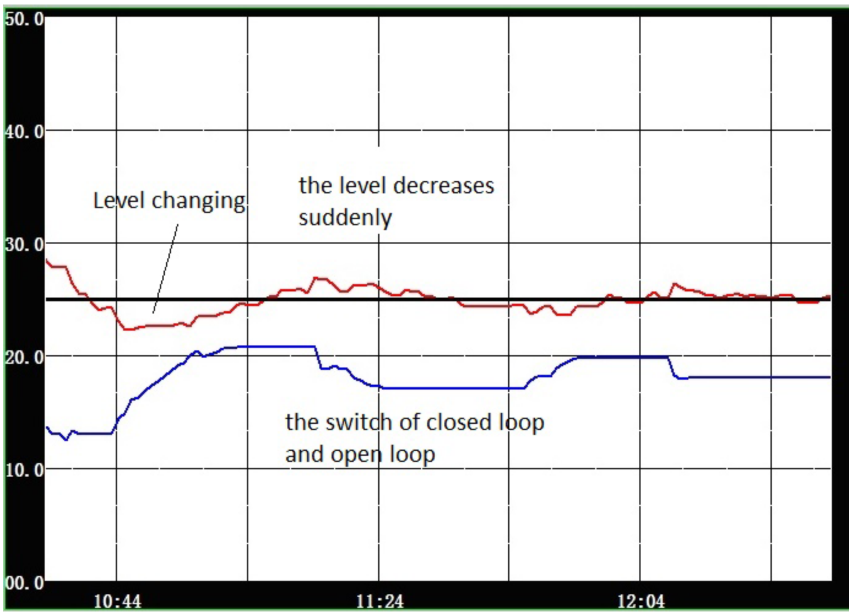

FIGURE 13. Test of eliminating disturbance

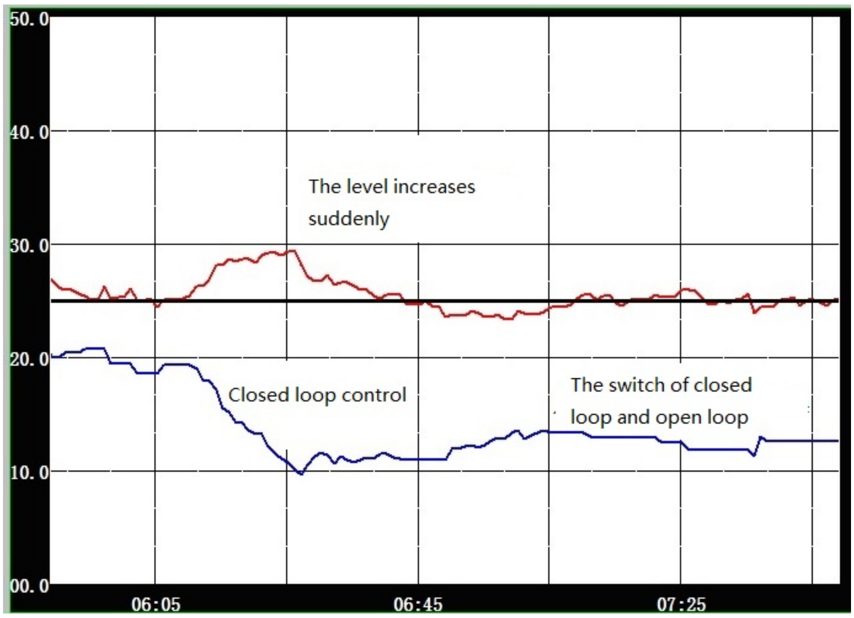

FIGURE 14. Test of eliminating disturbance

2) The constant control and tracing control of temperature, pressure, flow, and level in process control.

3) Automatic drive system, such as autonomous vehicles, autonomous airplane, robot, and a small intelligent car.

4) Plant control with a large or pure time delay is effective because different strategies and methods in different control stages, the switch of closed-open loop control according to the controlled variable states, and a variable sampling period in the control process are utilized. Plant control can overcome the shortcomings of the Simith predictive control algorithms and Dahllin control algorithms, which depend on the system mathematical model.

5) Other control systems can be controlled by human manual control. For example, the Hatch measuring and control system is introduced in [9].

The natural hatching process was realized by an experienced expert in the past. Thus, numerous human control experiences can be employed in an incubation control system. Many control methods, such as multivariable control, fuzzy optimizing control, decoupling control, and neural network control, are employed for incubation control. However, all control methods do not achieve the best result because an incubation control system is a multivariable, strongly coupled, disturbed and lagged system and traditional control methods cannot use human control experiences. The temperature, humidity and oxygen content are the controlled variables in the incubation control system, and many disturbance factors, such as outside temperature changes of the incubator, seasonal variation, and different stages of the incubation process, exist. Temperature is controlled by water heating or electrical heating and water cooling or air cooling. Oxygen content is controlled by ventilation. Humidity is controlled by humidification. One of the special features of an incubator is that the set value of temperature and humidity changes based on the egg types and stages of incubation process. Another special feature of an incubator is that the controlled variables act upon each other. For example, ventilation can make humidity decrease but also affect the temperature and oxygen content. The performance specifications of an incubation control system are efficiency and quality of incubation.

According to the analysis, an incubation control system is complex, and a better control performance cannot be achieved by only depending on traditional control algorithms. Thus, the HTSC can achieve a successful application in an incubation control system because it depends on not only the intelligent control algorithm but also human control experiences and skills.

The real curve of temperature control is shown in Figure 15, and the real curve of humidity control is shown in Figure 16. A sudden change, as indicated in Figure 15 and Figure 16, is caused by a disturbance in the ventilation rate. Another sudden change in Figure 15 is caused by humidity control. As illustrated in Figure 15 and Figure 16, the HTSC method can cope with some disturbances effectively because the Human-Thinking Simulated Controller counteracts the predicted disturbance effects according to the human control strategies.

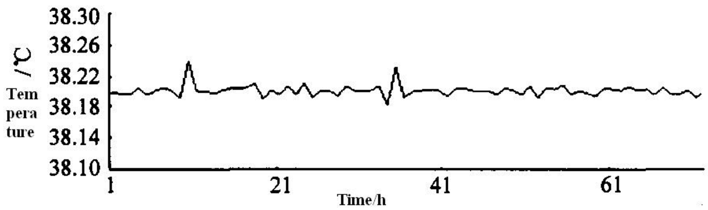

Figure 15. Real curve of temperature control

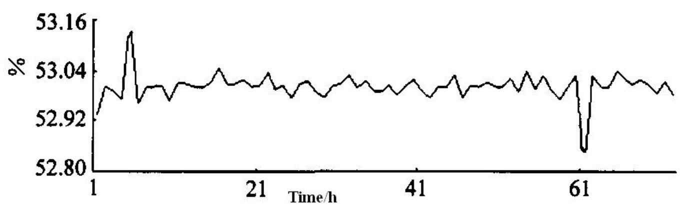

Figure 16. Real curve of humidity control

7. **Conclusion.** A new control theory is introduced in this paper. Due to limited space, this paper only discusses the main research on the theory. If readers want to understand the theory, including some concepts and definitions, they can reference the related papers.

The theory or cybernetics based on human control thinking, which is named Human-Thinking Simulated Control, simulates human control thinking and substantially differs from current theories. A man can ride a bicycle and drive a car very well, but he does not have complex algorithms and a mathematical model. How can he adequately control the car and bicycle? Human-Thinking Simulated Control attempts to discover the mechanism from the viewpoint of control thinking; it is the new cybernetics based on human control thinking.

The special characteristic of Human-Thinking Simulated Control (HTSC) is that it depends on human cognition and the human control thinking mechanism, which is the main difference between HTSC and current control methods. Since Human-Thinking Simulated Control was introduced by the author, some papers on HTSC have been published. Considerable research will be conducted in the future.

Based on the theory of HTSC, a new kind of control instrument has been designed and implemented: the Lon Human-Thinking Simulated Controller. The Lon Human-Thinking Simulated Controller is based on the LonWorks bus, simulates human control thinking and intelligence, and includes the methods and theoretical research results of HTSC. The controller consists of a double CPU and integrates embedded technology and LonWorks bus technology. The Lon Human-Thinking Simulated Controller can cope with the input and output of an analog signal, an on-off signal and a pulses signal and can communicate with other devices by RS-232, USB and LonWorks bus. Based on the special control algorithms of HTSC, the controller can be independently utilized and employed in the human body simulated intelligent distributed control system. The test results show that the Lon Human-Thinking Simulated Controller is suitable for process control, such as the control of temperature, pressure, flow, and level. The controller also achieved successful applications in the incubation control system, the cement production control system, and the small intelligent car control system.

The future research works about HTSC may pay much attention to the combination of the Human-Thinking Simulated Control and the deep-learning [20,21]. The deep learning network can realize the function of learning and accumulating experience similar to the human brain, and the deep learning control network based on human control thinking will be pointed out, which can be used to solve the control problem of complex system.

Professor Zadeh established fuzzy theory [6] and fuzzy control theory. However, the theory was not immediately recognized by other researchers. Thus, rediscovering the mechanism of human control thinking may require a considerable amount of time, and numerous researchers are needed to explore this topic. We hope that the successful day will come soon if we persist in going on the road of scientific research.

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