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Research Article

Fuzzy Control PID Parameter Tuning and Mathematical Modeling Based on Mobile Virtual Reality Technology

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A simple fuzzy rectification model based on mobile virtual reality technology based on PID parameters and mathematical modeling is reduced. In the PID control algorithm, parameter rectification is very important, which directly affects the control performance. The fixed parameters of the traditional method in some systems do not consider all the control indicators. Therefore, fuzzy control adjusts PID parameters and performs several experimental methods. The results show that the mobile virtual reality technology overadjusts the amount and rise time of the control system, when 5% of the response time, etc., are required; the parameters set by the ZN method cannot be taken into account. The PID parameter tuning method is practical in modern control and is an effective advanced method. This method has a certain adaptive ability, and the fuzzy control of PID parameters rectification based on mobile virtual reality technology can achieve a better control effect.

1. Introduction

The development of virtual reality and mobile virtual reality (VR) technology is amazing, and its successful application in various fields reflects that the technology has had a certain maturity. Virtual reality technology is an important direction of simulation technology and is the integration of simulation technology and computer graphics, human-computer interface technology, multimedia technology, sensing technology and network technology, and other technologies, is a very challenging crossover technology. Since the 1960s, modern control theory has been applied to industrial production processes. Military science and aerospace and many aspects, but the premise requires precise mathematical models [1], when the accused object or process is nonlinear, time degeneration, multiple parameters strongly curse, and random interference. When the process mechanism is complicated and the field measurement conditions are uncertain [2], it is impossible to establish a precise mathematical model of the accused object. Therefore, the use of traditional mobile virtual reality technology, including the control methods based on modern control theory, is often not as good as the manual control of a hands-on operator, which makes science and technology have to face up to an objective phenomenon, the fuzzy phenomenon. It is often not as good as manual control by a hands-on operator [3]. This makes science and technology have to face up to an objective phenomenon, a fuzzy phenomenon. L.A.Zadeh first proposed the notion of fuzzy mathematics and fuzzy control at its core to establish a mathematical model of linguistic analysis of complex systems or processes, making the human natural language directly transformed into a computer acceptable algorithmic language. The fuzzy theory has been developed for nearly 40 years, and it has developed extremely rapidly [4]. The study has roughly consists of the following aspects: self-adaption, a study on fuzzy reasoning strategy by self-learning fuzzy control theory, a study on the fuzzy identification model, a Study on the stability of the fuzzy control system, and hardware implementation of the fuzzy controller. At the same time, the engineering application of fuzzy control is also constantly developing; E.H.LMamdani, he was first a professor, at the University of London, England. E.H. LMamdani first controlled and successfully achieved the operation of the boiler and steam turbines using the fuzzy controller composed of fuzzy statements in 1974. Since the 1980s the fuzzy control has entered the usage stage [5]. The application surface is gradually extended to expand from large mechanical equipment and continuous production process as the main object to mass mechanical and electrical products. To complex big systems, intelligent systems, human, social systems, and ecosystems have been expanded. In terms of hardware, we will further develop mobile virtual reality technology, fuzzy reasoning, and other special chips to develop fuzzy control general system.

Virtual reality technology due to its widespread rapid development, virtual reality system according to the different forms of user participation is generally divided into four modes: desktop, immersive, enhanced, and distributed; immersive is mainly using helmet display, location tracker, data gloves, and other equipment, making participants get the feeling of the real scene. But in the most recent decades, various control theories have been greatly developed including studies on a variety of complex nonlinear systems and intelligent control systems. But in the current industrial control process [6], the most widely used is still the typical PID control that investigate its reason mainly because of its simple structure and has a certain robustness. Therefore, it can meet the general industrial control process [7, 8].

In particular, the first- and second-order dynamical processes. However, due to the nonlinear and time degeneration of the structure or model parameters of the accused object or when the accused process is disturbed by the outside world. This conventional PID control often does not meet the static, dynamic feature requirements. Intelligent control is a hot issue in the current control theory and application research. And, considerable results have been achieved. In the PID control algorithm, parameter tuning is very important. Its quality directly affects the control performance. For the simple control objects or the control objects of the known models, the PID control parameters correction methods using the traditional mobile virtual reality technology can generally get a good control performance. However, for complex control objects, or even simple time-varying systems, the fixed parameters of the traditional methods can not be taken into account one by one, and it is often difficult to get a very satisfactory control effect.

Therefore, for the problems of traditional methods, this paper proposes fuzzy control PID parameters and mathematical modeling of the PID parameters. It is therefore necessary to study how the idea of intelligent control theory to improve the traditional fixed constant PID control is used, especially the idea of fuzzy logic form a better mixed control and make it meet the requirements of a complex process. The online self-tuning of PID parameters using the fuzzy inference method not only maintains the advantages of simple principle, convenient use, and robustness of conventional PID robustness. And, with greater flexibility, the whole qualitative, better control accuracy, is currently a more advanced control system.

2. Research Technique

2.1. Effect of the PID Parameters on the System Performance. In the production site, the conventional PID parameter correction method is complex, and the parameters are often poor correction, poor flexibility, and the actual adaptability to the operating conditions is poor. For the shortcomings, many control systems organically combine expert control system, artificial neural network, fuzzy control, and optimal control, including expert PID control based on knowledge reasoning, rule-based self-learning PID control, etc. The PID control is made up of proportional, integral, and differential links. Its parameter refers to the proportional scale coefficient k_p, integration time constant T_i, and the differential time constant T_d. They can have a different impact on the system's performance.

(1) *Influence of proportional $k_p k_p$ coefficient on system performance.* The proportional coefficient $k_p k_p$ is increased, which will make the system movement sensitive, speed up. $k_p k_p$ large, the number of oscillations increases, and the adjustment time increases; $k_p k_p$ when too large, the system becomes unstable, while, in stable situations, article will increase the ratio coefficient $k_p k_p$, which can reduce the steady-state error and improve the control accuracy

(2) *Effect of the integral time constant $T_i T_i$ on the system performance.* When the integration time constant $T_i T_i$ is too young, the system will be unstable, when$T_i T_i$is too young, the impact on the system performance will be reduced, and $T_i T_i$ when appropriate, the transition process characteristics are ideal, while improving the control accuracy

(3) *Influence of the differential time constant $T_d T_d$ on the system performance.* When the differential time constant $T_d T_d$ too large or too small will make the system overshoot and too long adjustment time, $T_d T_d$ when appropriate, you can get a better dynamic effect

2.2. Classification of the Typical PID Controls. Typical PID controls include proportional, integral, and differential (PID) links with a transfer function.

$$G_c(S) = K_p + \frac{K_i}{S} + K_d S. \quad (1)$$

In type, K_p, K_i, and K_d are scale, integral, and differential gain, respectively. Another commonly used form of expression is:

$$G_c(S) = K_p\left(1 + \frac{1}{(T_i S)} + T_d S\right). \quad (2)$$

In type, $T_i = K_p/K_i, T_d = K_d/K_p$ $T_i T_i$ and $T_d T_d$ are the integral and differential time constants, respectively.

The rectification problem of the PID parameter is based on the accused object and the desired control characteristics to be achieved, adjusting $K_p K_p$, $K_i K_i$, and $K_d K_d$, perhaps $K_p K_p$, $T_i T_i$, and $T_d T_d$ three parameters making it meet a variety of different dynamic and static characteristics. The general adjustment method is based on the Ziegler–Nichols rule [9, 10]. Adjusted controlled systems have good antiload perturbation properties but are often accompanied by large overtuning and regulation times. Fuzzy logic is thought to be capable of somewhat humanlike tuning intelligence. Therefore, it is widely used adjusting PID parameters with mobile virtual reality technology is a hot issue of mixed control, and domestic and foreign scholars have done a lot of research, but many of the research results lack practical value due to the complexity of their models [11]. This paper introduces a fuzzy tuning method of PID parameters with a simple structure, easy to implement, and with good tuning properties.

2.3. Fuzzy Control Concept. Fuzzy control is a macroscopic approach to the control of the system, at its core is the rules of control described in language. Language control rules are often expressed as expert knowledge and experience in actual control in a "if...... (if-then)" manner [12]. The if section is also known as the conditional section. Is a proposition composed of the controlled quantity, etc, the then section, also known as the conclusion section. It is a proposition describing the amount of control. The biggest feature of fuzzy control is the representation of expert control experience and knowledge into linguistic control rules. These rules are then used to control the system. Thus, fuzzy control is particularly suitable for simulation experts' control of unknown, complex, and nonlinear systems of mathematical models [13, 14]. The fuzzy control system is similar to the common negative feedback closed-loop control system. The only difference is that the control device is implemented by a fuzzy controller. The fuzzy controller usually consists of the following parts:

(1) Standardization of the input and output quantity
(2) Fuzzy of the input quantity
(3) Language control rules
(4) Fuzzy logical reasoning
(5) Nonblurring of the output amount

The standardization of the input and output quantity means to limit the input and output of the standardized controller to the specified scope to facilitate the controller design and implementation. Because the input value of the controller is generally not a fuzzy number. So the blurring process is to convert the input value into a blur amount. Language control rules and fuzzy logic reasoning are the core of the controller. According to the fuzzy input quantity and the language control rules, the fuzzy logical input determines a distribution function of the output quantity. The nonblurring procedure converts the distribution function of the output into the normalized output. Finally, the controller converts the normalized output to the actual output value (i.e., the control amount) to control the system [15]. The deviation between a given value and the amount being controlled is the input of the controller. The controller controls the output value of the accused object by bias, making it stable at a given value.

Language control rules for fuzzy controllers. The fuzzy control rule is recorded as R, in the following form.

R_i: if the $X1$ is A_i 1, the $X2$ is A_iA_i 2,. . ., the Xn is the A_iA_i n, then the Y is $B_i = 1, 2, \ldots, m$. Here, the i represents the number of the rule, X_i ($i = 1, 2, \ldots, n$) for variables called the conditional part, Y is the variable in the conclusion section. A_iA_i, B_iB_i Separ, represent a variety of fuzzy subsets, also called fuzzy variables.

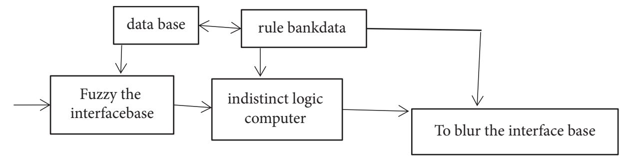

Figure 1: Composition of the fuzzy controller.

2.4. Composition of the Fuzzy Controller. A fuzzy controller is also known as a fuzzy logic controller because the adopted fuzzy control rule is described by fuzzy condition statements in fuzzy control theory. So the fuzzy controller is a language controller, so it is also known as the fuzzy language controller. Fuzzy controllers are generally implemented by computers, Implement the fuzzy control algorithm with computer programs and hardware [16, 17]. A computer can be a microcomputer, industrial control computer, PLC, and other various types of microcomputers. Programming languages can be an assembly language, an C language, etc. Now, there are also some fuzzy chips to implement fuzzy logic reasoning algorithms, which have become an important part of the fuzzy controller.

The fuzzy controller is divided from the function, mainly composed of four parts: fuzzy interface, knowledge base, fuzzy reasoning machine, and disblur interface as shown in Figure 1.

2.4.1. Design of the Basic Fuzzy Controller. Fuzzy control algorithm mainly refers to fuzzy, fuzzy reasoning, and clarity of the mechanism of f261. Based on the design of this fuzzy controller mainly includes accurate fuzzy quantity, fuzzy control algorithm design, fuzzy judgment of output information, and establishing fuzzy control query table:

(a) *Selection of Values of Language Variables and Language Variables.* The language variable of the fuzzy controller refers to its input and output variables. They are variables given in the natural language form. Since the fuzzy control rules are summed up based on the operator manual control experience [18]. The operator can generally only observe the output of the accused process and the amount of change. Therefore, the error and its change rate are usually used as the input language variable in the fuzzy controller. The amount of control is changed as the output language variable.

Controllers with this structure are called dual input single output fuzzy controllers. This fuzzy controller is more applied, reflecting that the fuzzy controller has nonlinear PD control rules.

(b) *A Fuzzy Subset On Language Variables.* Fuzzy subsets on language variable theoretic domains are described by membership functions. Membership functions can be determined by summarizing the operator's operational experience or ambiguous statistical methods. Fuzzy language values are actually the corresponding subset of fuzzy. And, the language values are ultimately described by the membership function. According to the control system characteristics, member functions of language values (i.e., semantic rules of language values) can be in the form of a continuous function. Sometimes it also occurs in a discrete quantization hierarchy. Both continuous membership functions and discrete quantization levels are distinctive, in general [19, 20]. The continuous membership functions are described more accurately. The discrete quantization level is simple and intuitive. Triangular membership functions with more computational convenience and small memory space are commonly used as membership functions of a subset of Fuzzy Figure 2.

In Figure 2, *e* represents the bias and *f* represents the amount of variation of the deviation.

In output: wait time (*t*) with a range of [0, 6], taking its theoretical domain as *Td* = {0, 1, 2, 3, 4, 5, 6). Its fuzzy subset of NB (is very few), NS(less), ZE (Medium), PS (more), and a lot of PB(s). Its membership functions are listed in Table 1.

Waiting Time Control Rule: the control rules summarized from human control experience are shown in Table 2. Representation of two inputs (*n*, *Q*) and a single output (*t*) language control policy consists of 25 fuzzy conditional statement rules.

2.4.2. Fuzzy Control Rules. Fuzzy control rules are a collection of fuzzy conditioned statements obtained by summarizing the operator's manual operating strategy in the control process. In addition to expressing the control rules in fuzzy conditional statements, it can also be represented by a fuzzy control status table. Common fuzzy controller structure includes single input single output fuzzy controller, double input single output fuzzy controller, and multi-input single output fuzzy controller.

2.4.3. Fuzzy the PID Controller. PID control was one of the first developed control strategies, It is also one of the most widely used control laws in the current industrial control. Due to its simple algorithm, good robustness, and high reliability, it is widely used in process control and its adjustment quality mainly depends on the control of each parameter. In the process control, the control effect is often not ideal due to the poor parameter rectification, therefore in view of this case, the article used the fuzzy parameter self-tuning PID control parameter tuning method.

2.5. Theoretical Analysis of the PID Controller Based on Mobile Virtual Reality Technology. Mobile virtual reality is a new type of human-computer interaction technology that has a wide range of application scenarios, such as multisensory training, pilot training, medical training, psychotherapy, and rehabilitation training, and this technology is the computer hardware and software synthetic artificial environment, making immersed in users produce vision, listening, touch, getting human-computer interaction experience, and striving to cause users as the real environment as the real world. The PID controller based on the mobile virtual reality

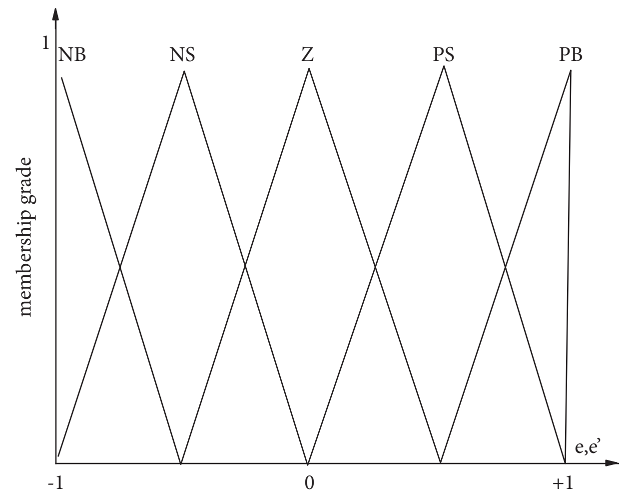

Figure 2: Enter a membership function curve for the *e*, *e'*.

Table 1: Membership table of the waiting time.

Language values	t: 0	1	2	3	4	5	6
NB	1.0	0.5	0.2	0	0	0	0
NS	0.2	0.8	0.6	0.2	0	0	0
ZE	0	0	0.5	1.0	0.5	0	0
PS	0	0	0	0.2	0.6	0.1	0.2
PB	0	0	0	0	0.2	0.5	1.0

Table 2: Fuzzy statement control rule table.

Q / n	NB	NS	ZE	PS	PB
NB	NB	NS	ZE	PS	PB
NS	NB	NB	NS	ZE	PS
ZE	NB	NB	NB	NS	ZE
PS	NB	NB	NB	NB	NS
PB	NB	NB	NB	NB	NB

technology is a linear controller that constitutes the control deviation according to the fixed value and the actual output value. The calculation process is as follows:

$$e(x) = a(x) - b(x). \tag{3}$$

The correction control process of each link of the controller is as follows: the automatic tracking control amount between the controller is positively proportional. In the event of deviation, the PID controller will automatically conduct automatic tracking control to correct the deviation. According to this principle, when the signal deviation changes greatly, the introduction of the early correction signal can improve the control efficiency and reduce the adjustment time.

$$W = \begin{cases} \lambda\left(a_1 p + (1 - a_1)PE\right), & P = 0, \pm 1, \\ \lambda\left(a_2 p + (1 - a_2)PE\right), & P = 2, \pm 3, \\ \lambda\left(a_3 p + (1 - a_3)PE\right), & P = 4, \pm 5, \end{cases} \tag{4}$$

Here, *E* represents conventional parameters. According to the value range of relevant parameters set, the optimal set

Table 3: Adjustments of the fuzzy rules for the PID parameter.

If Y_{os} very poor, T_5 good or good, follow ΔK_p it is negative, ΔT_i it is zero and ΔT_d it is zero
If $Y_{os}Y_{os}$ difference, T_5T_5 good or good, follow $\Delta K_p\Delta K_p$ it is negative and small, $\Delta T_i\Delta T_i$ it is zero and $\Delta T_d\Delta T_d$ it is zero
If $Y_{os}Y_{os}$ can, T_5T_5 very poor, follow $\Delta K_p\Delta K_p$ it is zero, $\Delta T_i\Delta T_i$ it's fair and $\Delta T_d\Delta T_d$ it is negative
If $Y_{os}Y_{os}$ can, T_5T_5 difference, follow $\Delta K_p\Delta K_p$ it is zero, $\Delta T_i\Delta T_i$ it is positive and small and $\Delta T_d\Delta T_d$ it is negative and small
If $Y_{os}Y_{os}$ good, tr difference and T_5T_5 difference, follow $\Delta K_p\Delta K_p$ it is zero, $\Delta T_i\Delta T_i$ it is positive and small and $\Delta T_d\Delta T_d$ it is negative
If $Y_{os}Y_{os}$ very good, tr difference and T_5T_5 very poor, follow $\Delta K_p\Delta K_p$ it is positive and small, $\Delta T_i\Delta T_i$ it is positive and small and $\Delta T_d\Delta T_d$ it is negative
If $e_{ss}e_{ss}$ very poor, follow $\Delta K_p\Delta K_p$ it is positive and small, $\Delta T_i\Delta T_i$ it's fair and $\Delta T_d\Delta T_d$ it is zero
If $e_{ss}e_{ss}$ very poor, follow $\Delta K_p\Delta K_p$ it is zero, $\Delta T_i\Delta T_i$ it's fair and $\Delta T_d\Delta T_d$ it is zero

of parameters is determined and combined with the PID controller to realize the design of the automatic tracking control scheme based on virtual reality technology.

3. Interpretation of Results

3.1. Fuzzy Control of the PID Parameter Tuning. The PID control parameter rectification of the mobile virtual reality technology is to determine the proportional contribution coefficient based on the accused object characteristics and the desired control performance requirements $\mathbf{K}_p$, integration time constant $\mathbf{T}_i$, and differential time constant for $\mathbf{T}_d$ three parameters. The earliest method used to rectify the PID parameters is the well-known Ziegler–Nichols method. There are two ways of the ZN method. One is to determine the open-loop step response of the control object. The other one is determined based on closed-loop properties containing only proportional control. The PID parameters can be obtained in the following two formulas.

Type 1: $\mathbf{K}_p = 0.6\mathbf{K}_u, \mathbf{T}_i = 0.5\mathbf{T}_u, \mathbf{T}_d = \mathbf{T}_i/4$.

Here, $\mathbf{K}_u$ and $\mathbf{T}_u$ are the proportional gain and oscillation period, respectively, when the closed-loop system is in a critical state under proportional control.

Type 2: $\mathbf{K}_p = 1.2/(\varepsilon\tau), \mathbf{T}_i = 2\tau, \mathbf{T}_d = 0.5\tau$.

Here, τ and ε are time of delay and flying speed, respectively.

Although the ZN method is convenient, sometimes the performance of the control system cannot meet the requirements, For example, mobile virtual reality technology overadjusts the amount and rise time of the control system, when 5% of the response time, are required, and the parameters set by the ZN method cannot be taken into account. The following examples illustrate a method to use fuzzy logic to rectify the PID parameters. This approach is based on the response properties of the control system, automatically adjusting the PID parameters and making the performance of the control system meet the given requirements. To evaluate the performance of the control system, the following four indicators are used: overshoot $\mathbf{Y}_{os}$, rise time $\mathbf{T}_r$, 5% response time $\mathbf{T}_5$, and quiet error $\mathbf{e}_{ss}$. These four metrics can be evaluated simultaneously by using fuzzy logic. For example, for the following control objects,

$$G_{(S)} = \frac{11.8}{1+24S}e^{-9S}. \quad (5)$$

Its order jump response: $\mathbf{Y}_{os}Y_{os} = 70\%$, $\mathbf{T}_rT_r = 70.5$, and $\mathbf{T}_5T_5 = 81$. The article now hopes to design a PID controller so that the characteristics of the closed-loop system meet the following requirements:

$$\mathbf{Y}_{os} \le 10\%, \mathbf{T}_r \le 70.5, \mathbf{T}_5 \le 81, \mathbf{e}_{ss} = 0. \quad (6)$$

When the PID controller is designed using the ZN method, the performance of the closed-loop system is as follows:

$$\mathbf{Y}_{os} = 70\%, \mathbf{T}_r = 70.5, \mathbf{T}_5 \le\ = 81, \mathbf{e}_{ss} = 0. \quad (7)$$

Obviously, the above-given control characteristics and the differences are required. Not only is the overshoot volume too big and the adjustment time T_5T_5 of the system is also longer. To achieve the required control performance, the article used the fuzzy control to automatically correct the parameters as follows:

$$\begin{aligned}\mathbf{K}_p^{(j+1)} &= \mathbf{K}_p^{(j)} + \mathbf{r}^{(j)}\Delta\mathbf{K}_p\\ \mathbf{T}_i^{(j+1)} &= \mathbf{T}_i^{(j)} + \mathbf{r}^{(j)}\Delta\mathbf{T}_i\\ \mathbf{T}_d^{(j+1)} &= \mathbf{T}_d^{(j)} + \mathbf{r}^{(j)}\Delta\mathbf{T}_d.\end{aligned} \quad (8)$$

where j represents the number of correction times and γ is the correction speed variable, this gradually decreases with the number of corrections. Apparently, the key to the parameter correction is how to determine the correct amount of the parameters based on the control metrics. To this end, fuzzy control can be used to build models, four performance metrics as input, and the correction of the PID parameters as output.

In the above-given model, the fuzzy rules for the PID parameter correction are as follows.

If $\mathbf{Y}_{os}Y_{os}$ right $\mathbf{A}_i$, $\mathbf{T}_r$ right $\mathbf{B}_i$, $\mathbf{T}_5$ right $\mathbf{C}_i$, $\mathbf{e}_{ss}$ right $\mathbf{D}_i$, follow $\Delta\mathbf{K}_p$ right $\mathbf{E}_i$ $\Delta\mathbf{T}_i$ right $F_i\mathbf{F}_i$ and $\Delta\mathbf{T}_d$ right $\mathbf{C}_iC_i$ ($i = 1, 2, \ldots, R$), inside $\mathbf{A}_iA_i$, $\mathbf{B}_iB_i$, …, $\mathbf{C}_iC_i$, the fuzzy sets of each variable.

3.2. For the Input Variables, The Fuzzy Set can be Set According to the Required Performance Indicators. When a fuzzy subset of the input and output is determined. The next step is to find fuzzy rules for a complete set of PID parameters. Although there is no systematic way to determine the best set of fuzzy rules, but for different systems, based on numerous experimental results, the appropriate set can be found. Table 3 is a set of rules summarized through a lot of simulations.

According to the response parameters of the control system, the PID parameters are automatically adjusted so

Table 4: PID parameters and control performance metrics.

	K_p	T_i	T_d	Y_{os}	T_r	T_5	e_{ss}
Before correction	0.246	15.9	3.98	50%	6.0	52.5	0
After correction	0.165	27.0	2.0	9.7%	10.5	39.5	0

that the performance of the control system meets the given requirements. Based on fuzzy logic, using the fuzzy system defined above, the modified value of the PID parameters can be obtained. Comparison of PID parameters and control performance indicators before and after correction using mobile virtual reality technology: see Table 4.

4. Conclusions

From the simulation results, using the PID fuzzy rectification model based on mobile virtual reality technology, the system output is smaller than the general PID control (such as antisaturation integral control), the adjustment time is faster, and the stability time is quickly reached, and has a certain robustness. Both the speed and stability are better than the general PID control, and it can meet the needs of various accuracy and stability control for industrial purposes.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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