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Marine Sink-Float Safety Device's Control System Based on Fuzzy Control

Zi Yue Wu[1], Jie Qi[2], Chen NanXue[3]
College of Engineering, Shanghai Ocean University, No.999, Hu ChengHuan Road, Lin gang new city, Shanghai, P.R. China
*Corresponding author, e-mail: zywu@shou.edu.cn[1], wuyu311125s@163.com[2], xuechennan@gmail.com[3]

Abstract
In order to ensure safety work of marine equipment, this paper introduces a kind of sink-float safety device which can match with marine equipment to realize protection work, and a fuzzy controller set up by fuzzy control algorithm. The data of the control system is collected by multi-sensor and filtered through the filter circuit. Under a 5 grade sea condition, the marine sink-float safety device can carry marine equipment, escaping from the harsh marine environment by diving to a certain depth. The simulation in MATLAB/Simulink shows that the control system could response fast and operate stably. Furthermore, it is able to control sink-float safety device efficiently and reach to the preset depth accurately. So we can guaranteethe operation of marine equipment reasonably.

Keywords*: sink-float, safety device, fuzzy control*

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1. Introduction

Due to China's economic and social development, land resources and space have been difficult to meet the demand of social development.People have to pay more attention to the development and utilization of ocean resources. There are increasing numbers of research about marine engineering equipment.Developing marine equipment has become one of the important research directions of state and university.For example, the maritime buoyage, AIDS to navigation lights, the ocean wave energy and wind energy power generation device as well as small marine monitoring platform [1]. Generally, many marine equipmentare always floating on the sea, which are directly influenced by various environmental factors, especially the strong wind and big waves, and it will make the equipment drift, overturn, even directly damage the marine equipment. Therefore, it is necessary to research safety device of marine equipment [2]. The marine sink-float safety device which we designed can cooperate with marine equipment to provide buoyancy,according to different marine equipments, the safety device can adjust the external structure or combination forms to meet the requirements of the sinking and floating. In bad environmental conditions, the control system will control safety device which can carry marine equipment descend to settled depth to avoid influence ofbig waves. And it also guarantees the operation of the marine equipment. In this process, the marine sink-float safetys' control system has great significance to guarantee the normal work of the equipment in marine work platform. At present, control method mainly include PID algorithm [3], "big system" theory of control algorithm [4], the fuzzy control algorithm [5, 6] and neural network control algorithm [7] as well as some algorithm improved by above several kinds of algorithm. The fuzzy control strategy is effective for systems which have large time constants and disturbances as well as fit for systems that lack of accurate mathematical model. Its usesregular mathematics variables replace linguistic variables and then combine with the physical system. Because the marine sink-float safety device is difficult to establish accurate mathematical model, so we use the fuzzy control algorithm to establish control system. The data of the control system collected by multi-sensor is filteredby filter method in order to eliminate errors and interference signals.In the end, the simulation of sink-float safety device control is done by MATLAB/Simulink.

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2. The Structure of Sink-float Safety Device

The sink-float safety device is shown in Figure 1, which mainly includes the solar panel, external gasbag and security buoy. The solar panel is embedded on the top of the external gasbag. The external gasbag is hanging around the edge of the security buoy, which can provides buoyancy to the sink-float safety device when it is on the surface of ocean. Security buoy is one of the most important parts, which can realize the sinking and floating by the way of water injection and drainage.

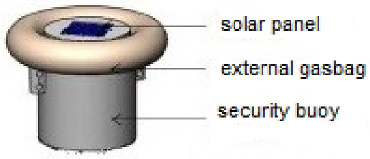
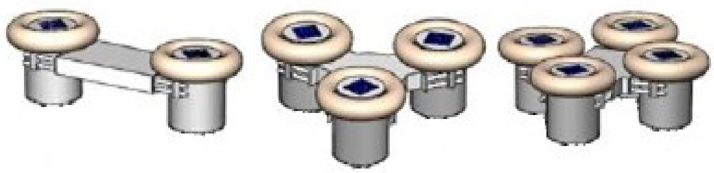


Figure 3. The Overall Structure of Marine Safety Device

The marine equipment is installed at the center position of the sink-float safety device, and the external gasbag and security buoy are uniformly distributed on the periphery. The maximum loading of sink-float safety device is 160kg.If the load is less than 160kg, we can increase the water storage of security buoy to reach the equilibrium state; if the load is heavier than 160kg, we can change the size of the security buoy and external gasbag to meet requirements. In addition, we can use a combination way of many devices to achieve the security state of equilibrium according to the weight of the load. As shown in Figure 2, three combination forms of sink-float safety device like this way a, b and c.The device is not limited to these three forms in figure, and the number and combination forms are also determined by different marine equipment.



(a) (b) (c)

Figure 2. The Combination Forms of the Sink-float Safety Device

The liquid level sensorsand pressure sensors are hanging around the outer of the security buoy, and they are also connected with the internal control module. Under a 5 grade sea condition, the control module will make sinking instructions and the actuator start working in security buoy. Therefore, water is flow into the security buoy, realizing the dive work gradually. At the settled depth, the sink-float safety device connected with marine equipment is upended in water. Generally, after 48 hours, the control module willsends a stop command automatically to another actuator, then the sink-float safety device will float to the surface of the marine. By the way, the safety device has completed the safety protection task.

3. The Design of Control System

In order to ensure normal work of the sink-float safety device and marine equipment, it is very important to design an efficient control system. By analyzing the characteristics of several current mainly control methods, and this paper is proposes a mode of fuzzy control to achieve safety and steadiness in the control system of marine sink-float safety device. Fuzzy control is based on linguistic variables rather than regular mathematics variables. To achieve a proper control result, one must give up traditional complex math equations and adopt the accumulated experience of manipulators to control the entire system.

3.1. The Overall Design of Control System

In order to make sure every factorinput to the control system accurately, we use five pressure sensors and two liquid level sensors to monitor signals. The liquid level sensors and pressure sensors are hanging around the outer of the security buoy. Use the actuators (the valve in the security buoy) realize the work of water injection and drainage. There is a filter circuit to filtering signalswhich collected by sensors as to eliminate interference. Otherwise, we use fuzzy control algorithm to design a fuzzy controller to control actuator. The overall system structure diagram is shown in Figure 3.

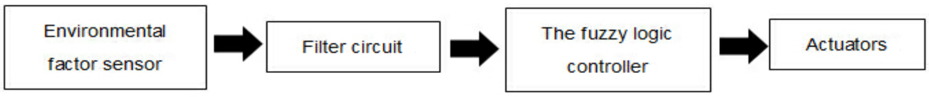


Figure 3. Overall System Structure Diagram

3.2. Filtering Principle

The marine sink-float safety device floats on the sea, which is directly influenced by the various environmental factors, so it necessary to design a filter circuit excluding the fault of sensors and other interference error signals generated by the outside world. The marine sink-float safety device carried marine equipment dive to a certain depth to avoid bad environment in a 5 grade sea condition or more than 5 gradecondition. According to hydromechanics analysis method [1], ata 5 grade sea condition, the detectedpressureof wave detecting unit is about 350N. Therefore, the filter circuit should rule out the signals beyond 0-360N before sinking.

3.3. The Structure of Fuzzy Controller

The difference between fuzzy control system and general control system is the controller designed by fuzzy controller. This system is a double input and double output control system. There are two actuators aim to different working process,and one of the actuators is used for drainage and another is used to water injection. The basic structure of the fuzzy controller includes four parts: fuzzification, fuzzy knowledgebase, decision making and defuzzification [8-11], it is shown in Figure 4.

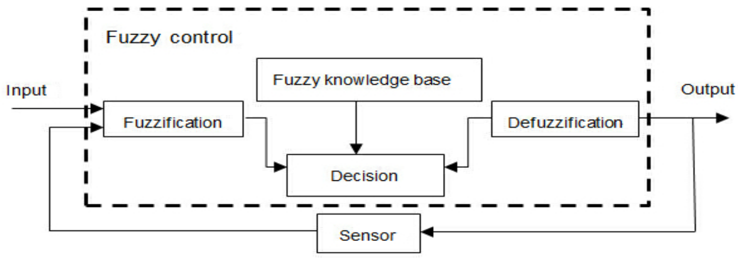


Figure 4. Basic Structure of Fuzzy Controller

3.3.1. Fuzzification

For an actually control process, there is always a range of input to fuzzy controller, which is called the “domain”. The mainly purposeof fuzzification isthe domain transformation, namely, giving assignment to the language variable. Otherwise, we should define language variables of input and output. The depth deviation"e" (stated depth R – measured depth Y) and the rate of depth change"ec" serve as the input variables of the fuzzy control. The basic domain of depth deviation "e"is [-5, 5], m and the basic domain of depth gradient"ec" is [-1,1], m/s. We also choose the type of membership function is Gaussian function which has control characteristic of stabilization and low sensitivity. The membership function of input e and ec is shown in Figure 5. The membership function of output is shown in Figure 6.

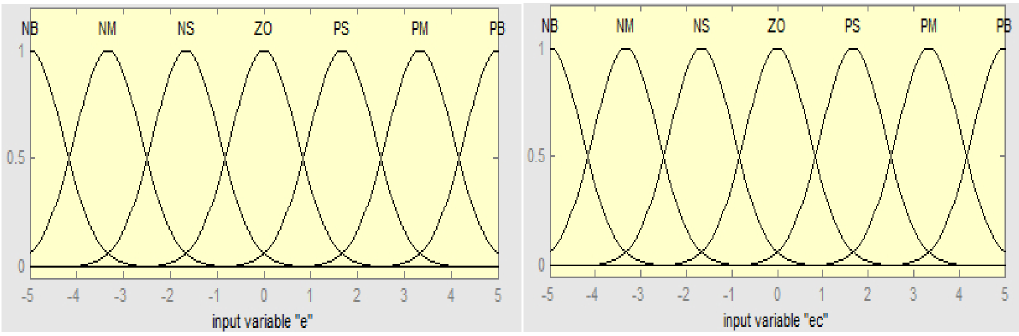


Figure 5. The Membership Function of Input "e" and "ec"

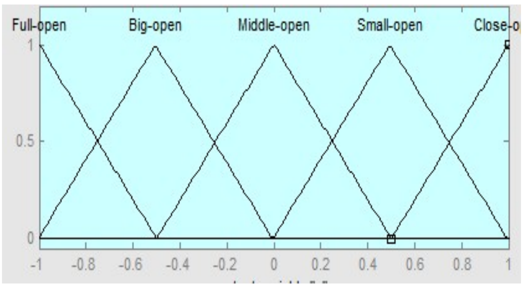


Figure 6. The Membership Function of Output "U"

3.3.2. Fuzzy Knowledge Bank

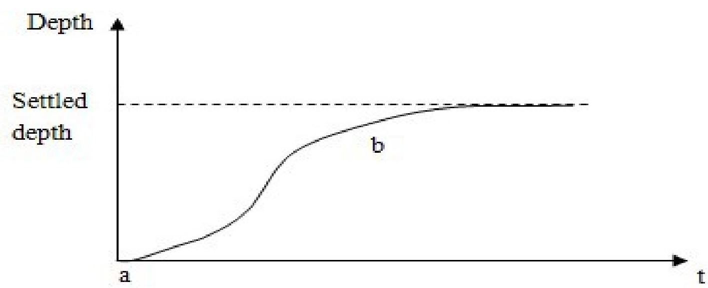


Figure 7. The Process of the Device Diving

The fuzzy knowledge bank includes database and rule base. The database mainly includes the membership function of language variable and transform factor etc. The rule baseincludes a series of control rules which represented by language variables. In the fuzzy control process, the control rule is the core of fuzzy controller, which directly affects the control performance of the control system.The design principle of fuzzy control rules is the dynamic and static response of the system output is the best. When the error is large, it should to eliminate the erroras soon as possible; when the error is small, the selection of input mainly to avoid overshoot.The fuzzy control rules can be written in the form of the following statement :$\mathrm{IF\ E} = \mathrm{A_i\ AND\ EC} = \mathrm{B_j\ THEN\ U} = \mathrm{C_{ij}}$. As shown in Figure 7, it is the expected process of marine sink-float safety device diving to a certain depth. At the beginning of diving (near the point a), the depth deviation is positivebig and the rate of depth change is very small, it is necessary fully-open the value to eliminate the deviation.So we can concludethat the rule near the point "a"is:If ("e" is PB) and ("ec" is ZO or PS) then ("U" is FO). Near the point "b", the depth deviation "e" is very small and the "ec" is bigger, therefore, it needs a signal to prevent overshoot and shock of the system at the moment. Therefore, the rule near point "b" is: If ("e" is PS) and ("ec"is PB)then ("U" isSO). Similarly, we can conclude the other control rules.

3.3.3. Decision Making

The core of fuzzy control is decision making, which includes "on-line calculation" method and "check the table" method.In actual control process, the fuzzy quantity is transformed into clear quantity, and then the clear quantity in the domain is transformed into practical control variable. The fuzzy control rules are shown in Table 1.

Table 1. Fuzzy Control Rules

E \ U \ EC	PB	PM	PS	ZO	NS	NM	NB
PB	MO	MO	BO	FO	/	/	/
PM	SO	SO	MO	BO	/	/	/
PS	SO	SO	SO	SO	/	/	/
ZO	CO	CO	CO	CO	CO	CO	CO
NS	/	/	/	SO	MO	SO	SO
NM	/	/	/	BO	BO	MO	SO
NB	/	/	/	FO	BO	MO	MO

3.3.4. Defuzzification

The fuzzy subset is obtained through fuzzy inference need translate into precision value by defuzzificaton, in order to get the final control output. Defuzzification is based on the fuzzy relation R = A * B * C (A is depth deviation "e", B is rate of depth change "ec") to compute the control output for each combination of input. The common method of defuzzification is maximum membership degree method and centroid method. Generally, the centroid method is the better method rather than others and it can be calculated by the formula. We use the centroid method to defuzzificaton, translating fuzzy quantity into precision value.

3.4. The Design of Anti-jamming Differentiator

In this control system, we use two-dimensional fuzzy controller. The depth deviation "e" and depth gradient "ec" serve as the input variables of the fuzzy control, but the "ec" is differential signal. Therefore, it is necessary to add the differentiator to the controller. Due to differential signals processed by common differentiator will produce burr and appear distortion, we use the real optimal control synthesis function, named function fsun(), to achieve differential signal. By the way, it can improve the control efficiency of fuzzy controller.

For a second order dispersed system:

$$x(k+1) = \begin{pmatrix} 1 & h \\ 0 & 1 \end{pmatrix} x(k) + \begin{pmatrix} 0 \\ h \end{pmatrix} u, |u| \le r. \quad (1)$$

The optimal control synthesis function of discrete system $f\,\mathrm{sun}(\mathrm{x}_1(\mathrm{k}), \mathrm{x}_2(\mathrm{k}), \mathrm{r}, \mathrm{h})$ [12, 13] is:

$$\begin{cases} y = x_1 + hx_2 \\ k' = \frac{1}{2}\left(1 + \sqrt{1 + {8|y|}/{h^2 r}}\right) \\ k = sign\left(k' - f\mathrm{ix}(k')\right) + f\mathrm{ix}(k') \\ \mathrm{f\,sun} = -\mathrm{rsat}\left(x_2 + {y}/{h}, hr\right), |y| \le h^2 r \\ \mathrm{fsun} = -\mathrm{rsat}\left(\left(1 - \frac{1}{2}k\right)s - {x_1 + khx_2}/{(k-1)h^2 r}, 1\right), |y| > h^2. \end{cases} \quad (2)$$

Based on the optimal control synthesis function: $\mathrm{f\,sun}(\mathrm{x}_1(\mathrm{k}),\mathrm{x}_2(\mathrm{k}),\mathrm{r},\mathrm{h})$, we can establish the discrete optical feedback system as follows:

$$\begin{cases} x_1(k+1) = x_1(k) + hx_2(k) \\ x_2(k+1) = x_2(k) + hu, |u| \le r \\ \mathrm{f\,s} = \mathrm{f\,sun}(x_1 - x, x_2, r, h_0) \end{cases} \quad . \tag{3}$$

Anti-jamming differentiator is a better differentiator which can achieve very good differential signal by eliminating the external disturbances and provide the realized dynamic performance index of closed-loop system.

4. The Simulation of the Control System

The simulation model of the fuzzy controller [14] established by MATLAB/Simulink is shown in Figure 8. The AJD module is accomplished by S-function of anti-jamming differentiator and the S-function written in C language.

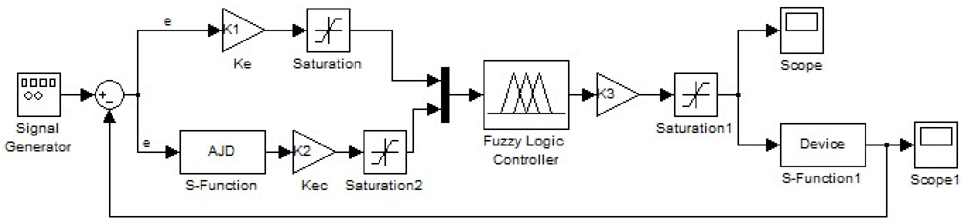


Figure 8. The Simulation Model of the Fuzzy Controller

At beginning of the sink-float safety device want to dive, the device at the surface of ocean, generally, we set the stetted depth is 4.5m, so the initial deviation ("e") is 4.5m. The expected simulation result of the device diving is shown in Figure 9.

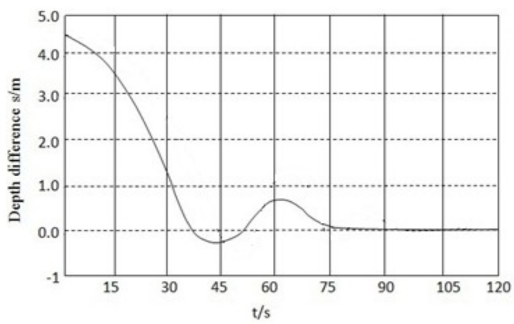


Figure 9. The Curve of Depth Variation

5. Conclusion

This paper introduce a marine sink-float safety device aims at the field of marine engineering equipment and design a control system for the device through using the fuzzy control method. The control system can control the marine safety device carried marine equipment reach a certain depth to avoid harsh sea environment automatically, ensuring the normal work of the marine equipment. As a result, the control system could response fast and operate stably as well as cost-effective. Comparing with manual control, the control system can reduce the workload of staff and improve the detection accuracy. Absolutely, the system not only can used in marine safety device but also can used in small submarines, amphibious robots as well as other areas of the marine engineering equipment.

References

[1] Wu Ziyue, Zhang Shuai, Gao ting, Qi jie. Design of the Secure System and Research of the Hydromechanics Based on the Small Marine Equipment. *Applied Mechanics and Materials.* 2013; 380-384: 241-245.
[2] Wang Zhong, Wang Chuankun. Analysis on RenewableOceanic Energy use in China. *Marine Environmental Science*. 2006; (25): 78-80.
[3] Chu Yuezhong, Tao Yonghua. Computer Simulation of Adaptive Fuzzy PID Control System Based on MATLAB. *Journal of Anhui University of Technology*. 2004; (1): 49-52.
[4] Wu Qindong, Sun Zhihui. Basic Overview of the Automatic Control Theory. *Science & Technology Association Forum*. 2011; (1): 87-88.
[5] Zhu Tong. Application and Research of PID Fuzzy Control. *Electric Drive Automation*. 2002; (24): 11-13.
[6] Liu Suqin, Liu Xinping, Qi Ping, Chen Jidong. Comparison and improvement of PID control algorithm and the fuzzy control algorithm*. Control Engineering of China.* 2003; (10): 51-52.
[7] Zeng Zhezhao, Wang Yaonan. The Application Research of Neural Network Algorithm in the Analysis of Nonlinear Systems. *Journal of Natural Science of Hunan Normal University*. 2007; (30): 56-60.
[8] Lou Shuntian. System Analysis and Design based on MATLAB.Xi'an: Xi'an Electronic Sience &Technology University Press. 2008.
[9] [9]He Ping, Wang Hongxu. The design and application of fuzzy controller. Beijing: Science Press. 1997.
[10]]Wang Lixin. The fuzzy system and fuzzy control. Beijing: Tsinghua University Press. 2003.
[11] Shi Xinming, Hao Zhengqing. The fuzzy control and simulation of MATLAB. Beijing: Tsinghua University Press. 2008.
[12] Sun biao, Sun xiuxia. Optimal control syntheses function of discrete2time system, Control and Decision. 2010; 3(25).
[13] Han JQ. Active disturbance rejection controltechnique. Beijing: National Defence Industry Press. 2008.
[14] Ying H. Fuzzy Control and Modeling: Analytical Foundations and Applications. IEEE Press, New York. 2000.