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Study On Intelligent Control System For Tower Cranes Based On ARM

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Abstract. Intelligent control is essential for tower cranes because the safety and work efficiency of construction. Firstly, an intelligent control system using ARM MCU and its auxiliary equipments, human-machine interface and control strategy were designed for tower cranes to realize monitoring and trouble shooting. Secondly, a fuzzy PID controller was adopted for tower crane. In the end, the experiment was made to test the intelligent control system. The test results show that the intelligent control system can achieve the national standard on tower cranes; also, it can save time, increase work efficiency and provide other auxiliary functions; in addition, the fuzzy PID controller is superior to conventional PID in intelligent control for tower cranes; accordingly, the intelligent control system has a promising application in the tower cranes.

Introduction

Intelligent control is an effective method to command complicated operations of tower cranes[1]. With the china's gradual growth of construction, the high-rise buildings are increasing rapidly. As a result, tower cranes can be used widely to need the market demand. For example, there was an application of tower cranes in Beijing, China, as is shown in Fig.1. However, the existing tower cranes which had the poor safety reliability and the low level of intelligence in practice could not meet the actual requirements of the construction; whereas, intelligent control can improve the safety of tower cranes, save the energy, and increase the working efficiency. In addition, the advanced control strategy which must be fully used for intelligent control system can reduce operation costs and obtain excellent performance of tower cranes; therefore, with the continuous development of intelligent control system, the corresponding control algorithm also becomes increasingly demand to controller stability, comfort, and energy efficiency. Accordingly, the intelligent control system has become one of the main research topics on tower cranes.

Fig.1: An application of tower cranes in Beijing, China

However, the intelligent control of the crane is not an easy task especially when strict specifications on the swing angle and on the transfer time need to be satisfied. According to Wahyudi, a practical and intelligent controller for automatic gantry crane which consisted of nominal characteristic trajectory following (NCTF) controller and fuzzy logic controller was introduced and evaluated experimentally. The results showed that the proposed method is not only effective for controlling the crane but also robust to parameter variation[2]. According to Hanafy M. Omar, two controllers was used, one for the rotational motion of the tower and the other for the translational

motion of the trolley[3]. However, the above-mentioned control strategies would result in a complex structure of system which did not have a general performance and did not match with the other types engineering machinery. In addition, the PLC is used to the intelligent control system. According to Yifan Chen, a safety monitoring system was designed of tower crane based on PLC and touch screen[4]. However, PLC did not have an extensible performance in application and did not easy to combine with network.

In order to acquire an excellent universal and extensible performance which can used into other engineering machinery, especially a heavy and large engineering machinery, an intelligence control system utilizing ARM was designed in the study firstly; and then, a suitable control strategy is adopted and experiment was made to verify its ability. Fuzzy PID algorithm was used in the control strategy by ZLG's ARM board. And the influence factors are estimated by analyzing the fuzzy algorithm of intelligent control. The result showed that the system could improve construction site safety and work efficiency of tower cranes,

The Intelligent Control System

Structure Of The System. The intelligent control system is designed and developed by the ARM MCU and its auxiliary equipments. The ARM architecture has evolved to a point where it supports implementations across a wide spectrum of performance points. The architectural simplicity of ARM processors has traditionally led to very small implementations, and small implementations allow devices with very low power consumption.

The intelligent control system can be mainly divided into five units in accordance with their functions: data acquisition unit, communication unit, Single-chip (EasyARM615) unit, LED display unit, and power supply unit etc, as shown in Fig. 2.

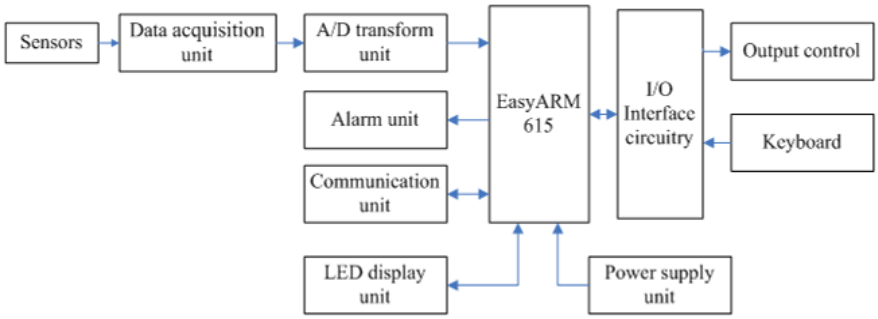


Fig.2: The intelligent control system

In the figure, data acquisition unit is mainly responsible of collecting some important signals of engineering machinery, such as water temperature, work pressure, and speed etc. Communication unit with network is mainly responsible for communications and data transmission. LED display unit is responsible for the current status of construction machinery. Single-chip unit which is the control core of system is responsible for coordinating the normal work of the various parts in system. Power supply unit is responsible for providing required voltage.

Because nearly all the supervised parameters will be attained from data acquisition unit, it is the base of the whole system. The sensor will be installed in the each relevant place. From the sensor, the corresponding parameters can be obtained. The intelligent control system can read the corresponding parameters from sensor, and monitor them in real time. Therefore, the parameters choice is important for the intelligent control system. In theory, the more control parameters is obtained, the better effect is achieved. But in fact, it is impossible considering cost and operation. Most of the parameters depend on the practice and experiment. Additionally, the intelligent control system must have alarm function in the abnormity and also receive consultation orders.

The Design Of Human-Machine Interface. As shown in Fig.3, Database design based on Lab windows/CVI.Lab Windows / CVI can achieve access and maintenance among a variety of heterogeneous database. In the figure, Lab Windows/CVI can receive data from test parameters and save them to database. Then, it can also read the data from the database. In addition, it can finish graphical display based on the read data.

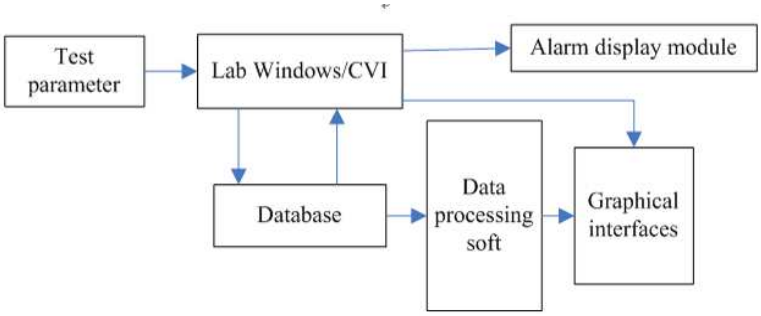


Fig.3 Database design based on Lab windows/CVI

CVI SQL Toolkit is available to use CVI software package to operate the database, which includes a series of high-performance operation functions. The comprehensive application of these functions can realize multi-functional database. After SQL Packet installation, Lab Windows / CVI SQL will be automatically registered an ODBC (Open Database Connectivity) data source on the machine, the data source is namely the data source used in the examples of Lab Windows / CVI SQL procedures.

In order to achieve Lab Windows / CVI to access database and realize the data management, the system uses the ActiveX Data Object (ADO) interface technology and ODBC (Open Database Connectivity) and select Microsoft's Access database and take SQL Toolkit as data management and software development tool.

Because of the more test parameter of construction machinery, it is important for user to design a good and clear interface of monitoring. Lab Windows / CVI can provides development environment to design a better interface based on the database. As shown in fig.4. There is a clear display interface

Fig.4 The interface of data display

3. Control Arithmetic and Simulation

The key of the intelligent control system is to determine and realize the control arithmetic. The suitable control arithmetic should have the tiny steady state error, quick dynamic response, and good robustness. In the study, the output is to make mean value of the steady working condition close to the ideal value. Besides, when the output deviates from the target value as the working condition changes suddenly, the control system should respond quickly and control the output close to the target value, and avoid the occurrence of poor performance of construction machinery. In view of the high nonlinearity and time delay of the system, the control method based on fuzzy PID is put forward.

Conventional PID control is widely used in industry because it is of simple structure, high precision, and has a good control performance for the linear system. But the control method only using PID has many questions. For example, it could not realize the control of large pure-lag and big inertia segments. Additionally, the conventional PID parameters have no self-adapting ability. Furthermore, the setting and optimizing of PID parameters depend mainly on the technicist regulating manually and the control effect is limited by their experience. So it is difficult for conventional PID to meet the actual control needs[5].

The fuzzy control is of better robustness and can better overcome some uncertainties in the system; however, its control precision is low. The fuzzy PID control used in this study combines the fuzzy control and typical PID control, making the system faster, with better robustness and higher control precision.

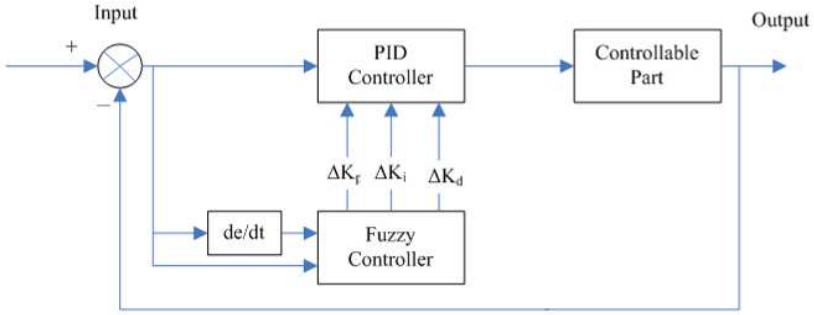


Fig 5: The Fuzzy PID controller

The fuzzy PID controller uses the error e and the rate of change of error Δe as its inputs. Its outputs are incremental value of PID parameters ΔK_p, ΔK_i and ΔK_d, as shown in Figure 5. The input and output parameters in the diagram respectively mean the desired and actual control parameters. The fuzzy PID controller can adjust online the three parameters according to the fuzzy control principle.

Table1: Rule table of fuzzy control

ΔK_p/ ΔK_i/ ΔK_d		e						
		NB	NM	NS	ZE	PS	PM	PB
Δe	NB	PB/ NB/ PS	PB/ NB/ PS	PM/ NB/ ZE	PM/ NM/ ZE	PS/ NM/ ZE	PS/ ZE/ PS	ZE/ ZE/ PM
	NM	PB/ NB/ NS	PB/ NB/ NS	PM/ NM/ NS	PM/ NM/ NS	PS/ NS/ ZE	ZE/ ZE/ PS	ZE/ ZE/ PM
	NS	PM/ NM/ NB	PM/ NM/ NB	PM/ NS/ NM	PS/ NS/ NS	ZE/ ZE/ ZE	NS/ PS/ PS	NM/ PM/ PM
	ZE	PM/ NM/ NB	PS/ NS/ NM	ZE/ NS/ NM	NS/ ZE/ NS	NS/ PS/ ZE	NM/ PS/ PS	NM/ PM/ PM
	PS	PS/ NS/ NB	PS/ NS/ NM	ZE/ ZE/ NS	NS/ PS/ NS	NS/ PS/ ZE	NM/ PM/ PS	NM/ PM/ PM
	PM	ZE/ ZE/ NM	ZE/ ZE/ NS	NS/ PS/ NS	NM/ PM/ NS	NM/ PM/ ZE	NM/ PB/ PS	NB/ PB/ PS
	PB	ZE/ ZE/ NS	NS/ PS/ ZE	NS/ PB/ ZE	NM/ PB/ ZE	NM/ PB/ ZE	NB/ PB/ PB	NB/ PB/ PB

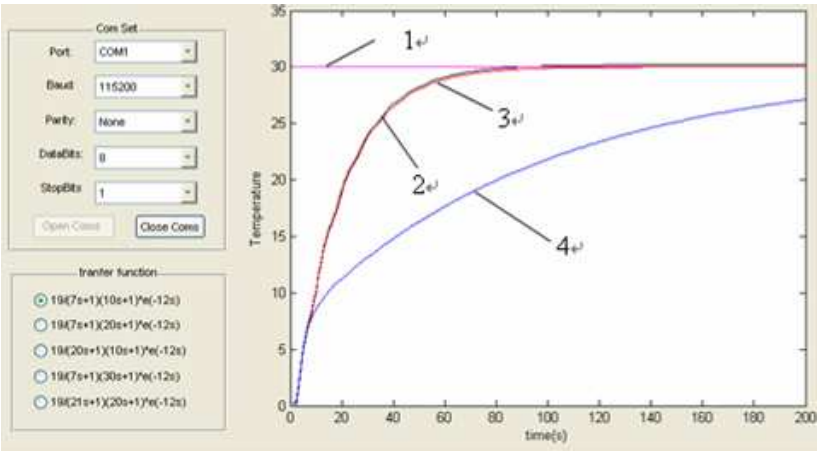
In the system, there are many control parameters. The trolley position and load swing are given a typical example in the study. Through the experiments, the normalized domain of the two input variables are taken as $e \in [0,12]$ and $e_c \in [-6,6]$, and their fuzzy sets are classified into seven fuzzy subsets(NB, NM, NS, ZE, PS, PM, PB). The normalized domain of the output variables are $\Delta K_p \in [0,5]$, $\Delta K_i \in [0,4]$, $\Delta K_d \in [0,3]$, and their fuzzy sets are classified into seven fuzzy subsets (NB, NM, NS, ZE, PS, PM, PB). The membership functions of input and output variables are assumed to be triangular types.

The role of the proportional coefficient of the PID controller is to increase the response speed and precision of the system. The role of the integral coefficient is to eliminate the static error of the system. And the role of the differential coefficient is to improve the dynamic property of the system. The rules of fuzzy control are designed according to the PID control rules and fuzzy control theory. The tuning rules of three parameters are performed as Table 1.

Finally, the actual value of the PID parameters are computed by

$$K_f = K_{f0} + \Delta K_f$$

Where f means p, i or d. K_{f0} is the initial value of PID parameters, K_{p0}=0.5, K_i 0=0.0055, K_{d0}=1.5



1-Desired value 2-Fuzzy PID by Matlab
3-Fuzzy PID by ARM 4-PID

Fig.6 The comparison of fuzzy PID and PID

In order to obviously evaluate the effect of fuzzy PID, the simulation can be made as shown in the Fig.6. The desired value is 30ºC; also, results in comparison of PID and fuzzy PID show that the performance of the fuzzy PID is better than PID controller and it is suitable for the intelligent system. The regulation time is shortened from 200s to 100s, and its shorten rate can reach nearly 50%. Furthermore, it is a better stability that the max error is reduced to 0.5ºC. So the result testified that fuzzy PID can save time and increase control efficiency Additional, the fuzzy PID simulation of Matlab is the same as the ARM. It is shown that the controller based on ARM is feasible and reliable.

Conclusions

The system has been experimented in a certain factory in Beijing, China. The test time lasted 5 months. The test result showed that the intelligent control system can achieve the national standard on test of tower cranes; also, the work rate can reach 92% beyond the 85% national standard; furthermore, the mean time between failures(MEBT) is 520 hours beyond the 200 hours national standard; and the other test parameters can obtain the check standard.

In conclusion, the study carries out a intelligent control system for construction machinery by using ARM MCU and designs the fuzzy PID controller in the intelligent control system. The following aspects are mainly concerned:

(1) Design and develop the embedded intelligent control system based on ARM MCU and its auxiliary equipments.

(2) Realize fuzzy PID controller in the intelligent control system.

The result testified that the system can save time, increase maintenance efficiency, and provide other auxiliary functions. So the Intelligent control system has a practical significance in the modern construction machinery. Also, the performance of the fuzzy PID is better than PID controller and it is suitable for the intelligent control system.

Acknowledgements

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