# Design of Intelligent Control for Port Crane

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**Abstract:** Based on the analysis of the physical model of the crane, the mathematical model of the crane is established. Aiming at the feasibility of nonlinear model simulation, a direct simulation model of differential equations based on Matlab's Simulink interface is established. The establishment of the simulation model laid the foundation for the design of the control system, and also provided experimental objects for verifying other control schemes.

**Keywords:** simulation model; port crane; classic feedback control; PID

## 1. Introduction

A crane, also known as a crane, is a mechanical device that uses a cable on a chain to lift and move heavy objects. A port crane is a carrier that transports containers to the cabin. In order to improve the production efficiency, the effective control of the crane has been studied at home and abroad, generally from the accurate positioning of the crane position and the swing of the suspended goods in the limited space, because the production site has a certain control environment for the crane. The interference, then the control system must have strong robustness.

The crane control system is a nonlinear system that can be approximated as a linear system by dynamics. The frequency method and root locus of traditional control theory can be used to design, and the control methods based on the state space equation of modern control theory [1,2] are established. They are well used in crane control. However, the control effect [3] is not very satisfactory for different environments.

## 2. Subject Content and Requirements

### 2.1. Purpose and Significance of the Topic

Port cranes are the carrying equipment for lifting containers to the cabin. In addition, cranes are also an important means of transportation in national production. They use advanced control methods to improve their work efficiency and reduce the dangers at the work site. Practical and economic significance. On the other hand, the computer simulation model of the crane as a nonlinear object coupled with multivariate can be used as a good representative object for the application, verification, development of modern control theory and intelligent control theory. The computer simulation research on crane control also accumulated experience for computer modeling and simulation for some nonlinear objects in the graphic simulation environment of Matlab.

## 3. Establishment of Port Crane Simulation Model

### 3.1. Mathematical Model of Crane

As shown in "Figure 1," the horizontal direction of the crane is controlled by the force *f*. Since the crane model has the characteristics of multivariable and high coupling, it is difficult to adopt the general force analysis method. Therefore, the Lagrange equation is used to establish a mathematical model of the crane.

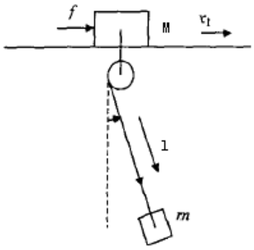


**Figure 1.** Crane physical model.

### 3.2. Simulation Model of Crane

#### *3.2.1. Direct differential equation simulation*

The crane system is a nonlinear system. The traditional method simulation model is based on the linearization of the model and is established for different control schemes. It is proved that they are correct for the modeling of linear systems, but they are compared with the real model. Not accurate enough. This needs to be improved, and the improved modeling method should be suitable for operation in Matlab's Simulink graphics simulation environment, in addition to ensuring the accuracy of the model. The direct differential equation simulation method can be competent.

The general model under Simulink is simulated using numerical integration, and the applied simulation algorithm relies on the model to provide its continuous state differential capability. The theoretical basis of direct differential equation simulation is the numerical calculation method of higher-order multivariate ordinary differential equations. For multivariate high-order constant coefficient differential equations, the first step is to perform the stepwise reduction of higher-order differential terms as well as the n-order ordinary differential equations. In the second step, in the iterative calculation process, the other variable machine differentiation is treated as a constant coefficient, and the value of all variables is updated every time the iteration loops the knot.

*3.2.2. Establishing a Simulation Model*

In order to improve the computational efficiency, the intermediate variables frequently quoted are also set as ordinary computational variables. In the simulation experiment, it is often necessary to check the system parameters, such as the mass of the weight, the length of the rope, and how robust the control system [4] is when changing. Therefore, the quality and length are also set as variables.

It should be pointed out that any parameter in the system of motion equations can be set as a variable, which is controlled by the program or operator during the simulation. The simulation model of "Figure 2" is built in Simulink.

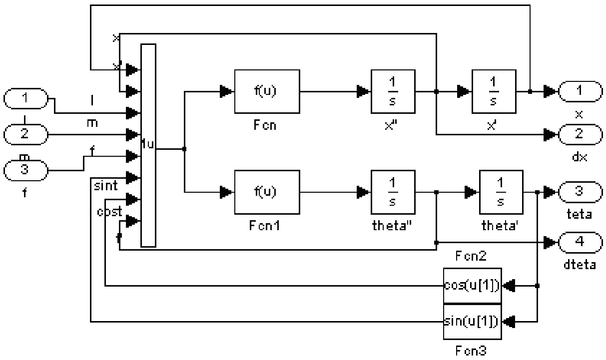


**Figure 2.** Crane nonlinear simulation model.

## 4. Traditional Control of Port Crane

### 4.1. Classic Feedback Control

This section discusses cascade double closed-loop control [5] in the ideal state of the crane to understand the control characteristics of the crane in an ideal state. When the system is in the open loop state, the response of the swing angle is sinusoidal when the disturbance is received. In fact, the port crane is gradually stabilized under other resistance, and the crane displacement and the swing angle depend on each other. From the control point of view, when the crane has not reached the target position, then when the displacement error is large, the force to the crane system is greater, and the swing angle response is also larger. As the displacement error is smaller, the swing angle is smaller; when the weight reaches the target, the force applied to the crane is opposite to the previous one; when the error is reduced to zero, the force is reduced to zero and the swing angle is reduced to zero. On the basis of the ideal state, considering the simulation of the non-ideal state, the results are basically the same. However, considering other nonlinear systems, the effects of interference are not as simple as control. Its cascade feedback simulation model is shown in "Figure 3".

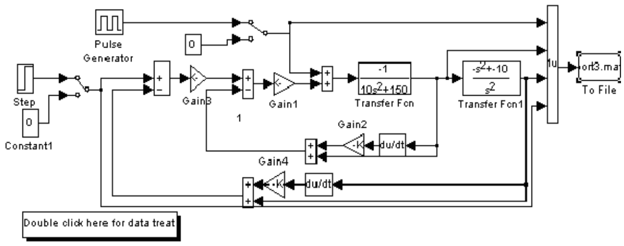


**Figure 3.** Cascade Feedback Control Simulation Model.

### 4.2. Modern Control Theory Control

Classic feedback control [6] is mostly based on output feedback, while modern control uses state space feedback control because the state of the system can completely determine the future of the system.

For the crane system, if the position is observable, it is the output of the system, and it is also a state of the system. At this time, it does not need to be reconstructed, and the observer can be designed as a reduced-order observer. According to the observer equation, the simulation model is built as shown in "Figure 4".

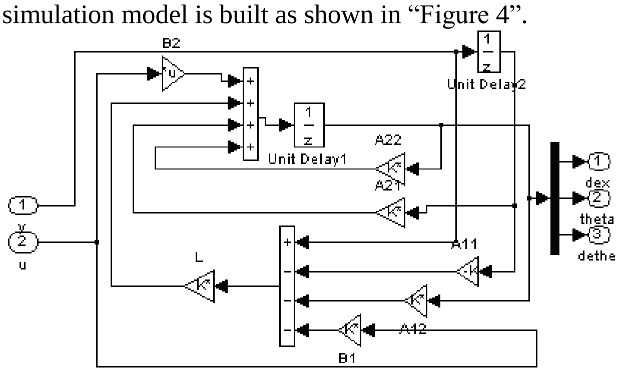


**Figure 4.** Simulation model of dimensionally reduced state reconfiguration.

The state refactoring test simulation model is shown in "Figure 5".

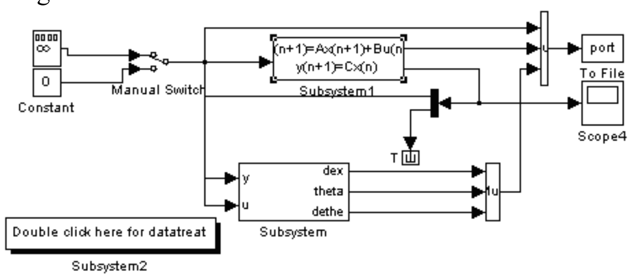


**Figure 5.** State reconstruction test simulation model.

### 4.3. Optimal Control

The optimal control problem is for a controlled object, according to a certain (optimal) performance index that is desired to be satisfied, that is, the requirements of the integrated system in terms of dynamic quality and related performance, find out the control law, design control The closed loop system achieves optimal control corresponding to performance specifications. For linear systems, the integral of the state variable and the quadratic form of the control variable is taken as the performance index, which is called the lq index optimal control.

Classic feedback cascade control and modern control are applied to the crane system. Since the transfer function of the crane is a high-order system, if the feedback control is implemented on the actual system (regardless of the friction parameters), it is more complicated, so we ignore its friction parameters and establish cascade feedback control under its ideal state. The parameter setting method enables the crane to achieve rapid positioning and anti-roll angle, which gives us an understanding of the control details of the crane. Then consider the cascade feedback control of the actual crane system (considering the friction parameters).In modern control, considering the actual crane system, because it is a model of state space description, it is necessary to achieve stable control of its parameters than the classical closed-loop control parameter setting.

## 5. Intelligent control of port cranes

### 5.1. Control Motor Model

In an automatic control system, a motor is a device that converts electrical energy into mechanical energy and is an important device for the control system. DC motors are commonly used equipment. Assume that the horizontal control system of the crane uses a DC motor. The system model diagram is shown in “Figure 6”.

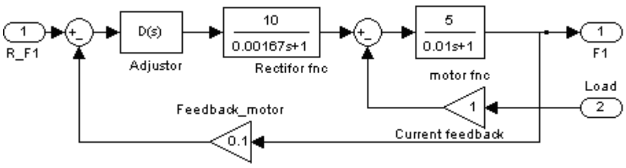


**Figure 6.** Control motor model.

### 5.2. Port Crane Pid Control

In the case where the parameters of each system are known, the control requirements can be achieved by using the traditional multi-ring pid control. Establish a crane horizontal pid control system as shown in “Figure 7”.

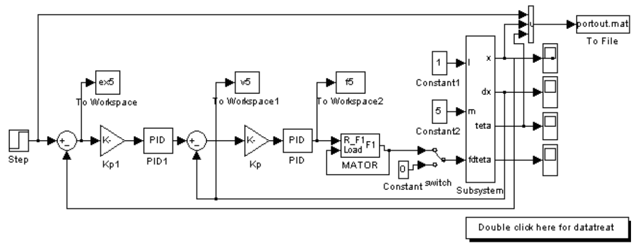


**Figure 7.** PID control of the port crane.

### 5.3. Neural Networks and Fuzzy Control

Neural networks and fuzzy logic control [7] are the most commonly used controls. Neural network control has the following advantages:

(1) Neural network has nonlinear approximation ability. Because neural network has the ability to approximate nonlinear mapping, neural network has great development prospects when using nonlinear process control.

(2) The neural network has the function of learning and self-adaptation. It can find the intrinsic connection between input and output according to the past records of the system, so as to obtain the answer to the question; this process does not rely on the prior knowledge of the problem and regular, so the neural network has better adaptability.

(3) Neural network has multi-input and multi-output network structure to handle multivariate problems

However, from the perspective of modeling, the neural network is a typical black box-type learning mode. When the learning is completed, the input and output relationships obtained by the neural network cannot be expressed in an easily accepted manner. And the choice of the number of layers of the neural network is a very empirical problem. At present, in the control, the neural network is combined with the traditional control pid, fuzzy logic control, etc. to exert its advantages. Fuzzy control is a rule-based control that mimics human control and controls complex control objects.

Compared to traditional control, fuzzy logic control has the following advantages:

(1) Fuzzy control does not depend on the precise mathematical model of the controlled object, relying only on expert knowledge and operator experience;

(2) Fuzzy control has strong knowledge expression ability, which can describe and refine expert knowledge and operator experience in the form of rules;

(3) Fuzzy control has strong reasoning function. Fuzzy logic reasoning can realize the decision process similar to human;

(4) Fuzzy control has better robustness.

However, fuzzy logic control is limited to empirical design, and it is difficult to formulate inference rules and adjust the disadvantages of membership functions.

Aiming at the advantages and disadvantages of neural network and fuzzy logic control, people combine the two advantages of fuzzy theory knowledge expression and neural network self-learning ability to learn from each other and improve the learning ability and expression ability of the whole system.

### 5.4. Matlab Auxiliary Anfis Design

MATLAB’s fuzzy toolbox provides the main function anfis and graphical tool function anfisedit for the adaptive neural network fuzzy inference tool [8]. They obtain the parameters of the librarian function of the fuzzy inference system by adaptive neural network learning method, function anfis and graphical the function of anfisedit is similar.

Matlab’s anfis modeling process is very similar to the system identification method. First, assume a parametric model structure, then obtain a set of input/output data pairs and combine them into training data for the anfis algorithm according to a certain format. At this time, the anfis method can be used to train the previous parametric fis model, and the parameters of the membership function can be adjusted according to a certain error law, so that the fis model can continuously approximate the given training data. This modeling approach works well if the data is a good representation of the features that are needed.

According to the pid controller coefficient, different input and output data of the crane system are obtained, which well reflects the characteristics of the crane control system when the rope and weight quality change. Therefore, the adaptive neural network fuzzy inference system can be applied to establish a fuzzy logic controller for the crane horizontal system which is robust to rope length and weight quality. However, if there is a requirement for the robustness of the length of the rope and the weight of the weight, the data to be trained will be large, so this section only discusses the fuzzy controller that is robust to the weight.

### 5.5. Fuzzy Control of Port Cranes

The modified fuzzy controller is used to replace the double-loop PID. The control simulation model is shown in "Figure 8". In the port crane fuzzy control simulation under the Simulink interface, the trained fuzzy controller must be exported to the MATLAB workspace. This must be written to be used before the model simulation to export the fuzzy controller to the workspace.

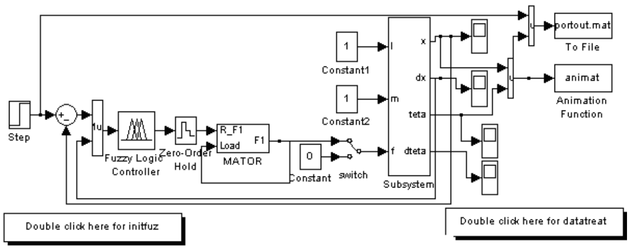


**Figure 8.** Fuzzy control simulation model of port crane.

## 6. Conclusion

This paper is based on the simulation experiment of port crane control. Firstly, the traditional control theory is used to control the horizontal movement of the port crane, but the traditional control has inherent disadvantages. In order to establish adaptive and robust control, this paper considers the advantages of neural network and fuzzy logic control, and uses adaptive neural network fuzzy inference system to establish a robust fuzzy controller for port crane control. And achieved good control results.

The design of the control system of the port crane should give full play to the advantages of numerical simulation, and use a variety of control schemes to control the system until it finds a control scheme that can make the system control performance the best. It should be pointed out that the fuzzy control scheme of intelligent control discussed in this paper has certain defects: First, there is a small amount of overshoot in the positioning. Second, there is a deviation in positioning. This is because the position error and position change are small, the corresponding control amount is also small, and it is very likely to keep a certain value unchanged. This causes the system to generate a steady-state error if the error is large. When the allowable range is exceeded, the fuzzy controller needs to be improved. The specific method can be self-adjusting the fuzzy linguistic variable domain of the fuzzy controller by applying the self-adjusting technique. Third, for a given signal greater than 1 m, the fuzzy controller also works, and the fuzzy domain must be expanded to increase the quantization factor of the domain. From the overall effect of control, the ANFIS-based fuzzy control scheme discussed in this paper is still successful.

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