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# Application Of The Three-In-One Control Platform Based On OPC In The Lifting-Sliding Stereo Garage

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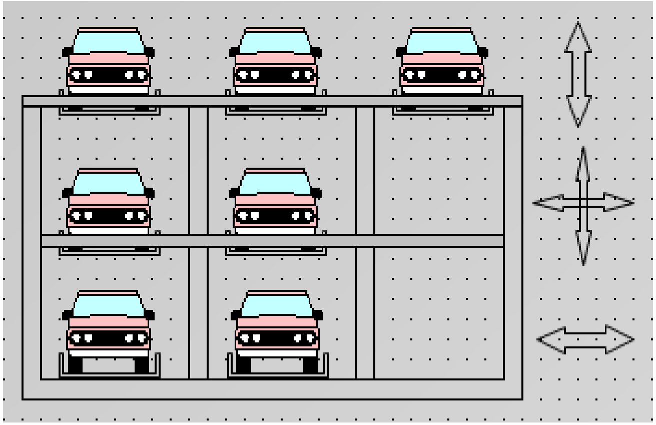
**Abtract:** *The three-in-one control platform includes MATLAB, WINCC and S7 300 PLC. In the platform, MATLAB communicates with WINCC through OPC and WINCC communicates with PLC. It is a control platform with WINCC as the bridge. The platform is designed to shorten the operating time of the lifting-sliding stereo garage, and at the same time to achieve controlling the stereo garage through monitoring interface. Genetic algorithm is designed with MATLAB for getting the optimal scheduling scheme of lifting-sliding stereo garage in the platform. Then the date was passed to WINCC through OPC. PLC conducts the scheduling of the stereo garage based on the date getting from WINCC, and through the WINCC to achieve real time picture monitoring and operating of the stereo garage. Under the same conditions, the control platform can get access to the vehicle in the shortest time.*

**Keywords:***Three-in-one control platform; Genetic algorithm; Optimal scheduling; Screen monitoring; OPC; Lifting-sliding stereo garage*

## I. Introductory

lifting-sliding stereo garage generates vertical channel by means of carrying boards' traverse, in order to lift the objective carrying board to save and take vehicles. Fig.1 shows a stereo garage with three layers and three columns. There are three slots in the top layer and two slots in the other layers, totally seven slots. The carrying boards in the top layer are only supposed to lift, and in the first layer they are only supposed to traverse.

Fig.1 3×3 Stereo garage model



## 1 Scheduling algorithm of stereo garage

The optimal scheduling scheme is obtained via genetic algorithm, which is designed with MATLAB.After encoding, decoding, selection, crossover,mutation, inversions and other operations on the feasible solutions that are generated randomly, we can get the best scheduling scheme of the stereo garage.

### 1.1 Encoding and Generation of initial population

Each individual is encoded with binary encoding. There are seven slots, and the length of each chromosome is 42. Every six bits represents the number and movement of a carrying board, and the first three bits represents the number, the last three bits represents the movement.There are five state of the carrying boards: Stay still(000), Move up(001), Move down(002), Move left(003), Move right(004). Because the code is generated randomly, the rest of the number 101, 110 and 111 need to be changed to 000, which can increase the number of static carrying boards, thereby reducing the number of calculations, so as to improve the efficiency of saving and taking vehicles.

Suppose the population size is 50, then 50 individuals can be randomly generated via the instruction “rand”. Instruction “rand (50,42)” can generate a matrix with 50 rows and 42 columns. Round the elements of the matrix with the instruction “round” to get the initial population. The specific program statement is “Population=round(rand(popsize,BitLength))”, in the statement, “popsize” represents the population size and “BitLength” represents the length of chromosomes.

### 1.2 Decoding

Convert the matrix with 50 rows and 42 columns to a integer matrix to get ready for calculating the fitness. The length of each chromosome is 42. Convert every three bits to an integer, then there are 14 elements in each row of the integer matrix.From left to right, the odd digits indicate the number of carrying board, and the even digits represent movement, and finally a integer matrix with 50 rows and 14 columns is obtained. Decoding formula is expressed as follows:

$$x=\sum_{i=1}^{k} b_i 2^{i-1} \qquad 1\text{-}1$$

### 1.3 Calculation of fitness

The objective function is the carrying boards’ running the shortest path under the condition of the carrying boards’ movement restriction, which is letting the total number of times of carrying boards’ movement to a minimum. In the step of decoding, a decimal integer matrix is obtained. The even digits in each row represent movement. Calculate the number of nonzero even digits to obtain the total number of times of movement. Fitness function is expressed as follows:

$$fit(x)=\begin{cases} \mathrm{c}_{\max}-f(x) \quad , \qquad f(x)<c_{\max} \\ 0 \quad ,Other \quad cases \end{cases} \qquad 1\text{-}2$$

Via the above formula 1-2, the objective function can be converted from minimum problem to maximum problem. In the formula, $c_{\max}$is a conservative estimated value defined by the objective function. The number of carrying boards of the stereo garage is 7. Taking into account the need of introducing a penalty term, take 200 as the value of $c_{\max}$. So as to ensure that the value of fitness will not be negative.

Since the stereo garage scheduling problem is a kind of constrained optimization problem, apply the penalty function to the genetic algorithm. When the movement violates the constraints, the penalty item will be added to the evolutionary function, which can reduce the fitness value of the individual that violates constraints. Different penalty parameters is designed for different constraint. Suppose $eval(U_i)$ is the sum of the number of times of carrying boards'movement and the penalty team.

Objective function: $f = \min\{eval(U_1) \quad eval(U_2) \quad \cdots \quad eval(U_{50})\}$.

Constraints:

a. Carrying boards on the top layer cannot move left and right, and carrying boards on the first floor cannot move up and down;

b. Two consecutive movement of Carrying boards cannot be the same as moving up and down;

c. The final movement must be the movement of the target carrying board,and must be moving down;

d. Carrying boards near the border of the stereo garage cannot move towards the border;

e. On the direction of carrying boards' movement must be empty.

The individual that does not meet these constraints will be punished. In this paper the penalty function is constructed with an improved Joines and Houck Method, which uses addition form to construct penalty function. Penalty term is constituted by variable penalty factors and penalties of violating constraints. Evaluation function with addition form is expressed as follows:

$$eval(U_i) = k_i + p(t,i) \qquad 1\text{-}3$$

$k_i$ indicates the total number of times of carrying boards'movement. Penalty function is expressed as follows:

$$p(t,i) = \rho_t{}^{\alpha} \sum_{j=1}^{N} d_j{}^{\beta} \qquad 1\text{-}4$$

In the formula, $t$ indicates iterations, N indicates the number of constraint equations, α and β are the parameters of adjusting the penalty value, $i$ indicates the i-th individual.

$$d_j = \begin{cases} 0\,, All\ movements of\ U\ meet\ j-th\ constra\text{int} \\ \text{n}M\ ,"n"\ movements of\ U\ don't\ meet\ j-th\ constra\text{int} \end{cases} \qquad 1\text{-}5$$

$$\rho_t = C \times t \qquad 1\text{-}6$$

In the above two formulas, M and C are constants, $\rho_t$ increases with the evolution.

Then after selection, crossover, mutation, inversions and other operations, the best individual can be obtained, which is the best scheduling scheme.This paper chooses roulette selection method, single-point crossover and uniform mutation.

### 1.4 Getting information about the current status of stereo garage

Before the computation of scheduling algorithm, MATLAB should obtain the information about the current status of each carrying board. The status information of parking slots is represented by 0-1 method. 0 indicates that the slot is empty and 1 indicates that the slot is not empty. The location information of the carrying board is represented by the matrix whose elements are the carrying board number, and 0 indicates that the carrying board is empty. For instance, from Fig.1 we can know that the matrix about the status information is $\begin{bmatrix}1 & 1 & 1\\1 & 1 & 0\\1 & 1 & 0\end{bmatrix}$, and the matrix about the location information is $\begin{bmatrix}1 & 2 & 3\\4 & 5 & 0\\6 & 7 & 0\end{bmatrix}$. The status information of parking slots is obtained by the photoelectric sensor, then be transferred to the PLC, and then be passed to WINCC. MATLAB can obtain information about the current information of stereo garage from WINCC via OPC protocol. According to the scheduling algorithm,the optimal scheduling scheme can be obtained. When the stereo garage is under operation, and when a viable movement appear, the two matrices will change.

### 1.5 Calling scheduling algorithm when saving and taking vehicles

Parking is operated on the interface of WINCC, which is divided into manual parking and automatic parking. It’s no need to call scheduling algorithm for manual parking. For the automatic parking, firstly the system will scan the status of each carrying board from the first layer to the top layer until finding an empty carrying board, then it will get its location information. If it belongs to the first layer, it is no need to call scheduling algorithm. If it belongs to other layers, the best scheduling scheme of it moving to the first floor should be obtained via scheduling algorithm. For taking car, firstly choose the “taking” button on the interface of WINCC, then choose the carrying board number. The system will get its location number. The follow steps are the same as that of the automatic parking.

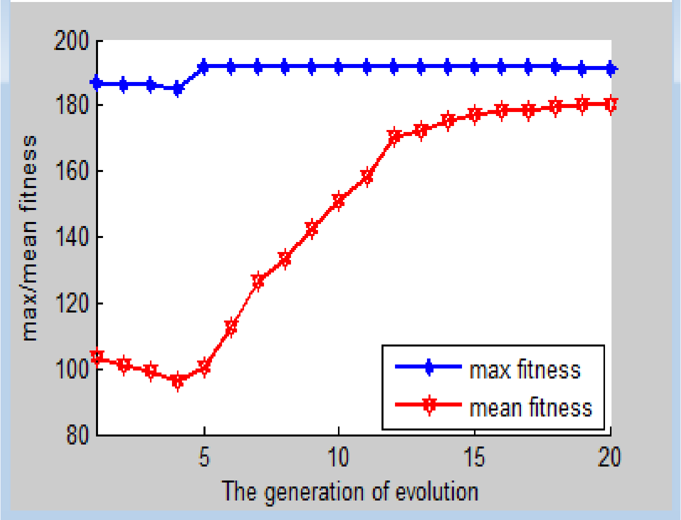
## II. Experimental results of scheduling algorithm

Program runs in MATLAB R2008a. Some parameters of scheduling algorithm are designed as follows: population size is 50, the number of iterations is 20, mating probability is 0.8, mutation probability is 0.01, the matrix about the status information is $\begin{bmatrix}1 & 1 & 1\\1 & 1 & 0\\1 & 1 & 0\end{bmatrix}$, the matrix about the location information is $\begin{bmatrix}1 & 2 & 3\\4 & 5 & 0\\6 & 7 & 0\end{bmatrix}$, penalty parameter C=0.5, $\alpha = 0.1, \beta = 1$ and M=6. Suppose the target carrying board number is 1. The results obtained are as follows:

Tab.1 The result of the best scheduling scheme

| Number of carrying board | Movement code | Movement |
|---|---|---|
| 5 | 4 | Move right |
| 3 | 0 | Stay still |
| 4 | 4 | Move right |
| 1 | 2 | Move down |
| 7 | 4 | Move right |
| 6 | 4 | Move right |
| 1 | 2 | Move down |

Fig.2 Trend of the fitness



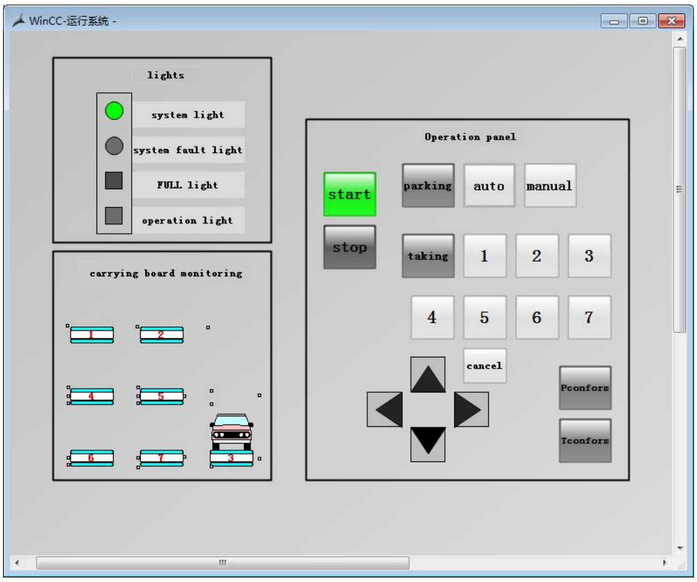
Tab.1 shows the optimal scheduling scheme. After six steps the 1st carrying board arrives at the first layer. The final location information of carrying boards is $\begin{bmatrix} 0 & 2 & 3 \\ 0 & 4 & 5 \\ 1 & 6 & 7 \end{bmatrix}$. The actual shortest path of putting the 1st carrying board to first layer is also 6 steps, so the calculated result is consistent with the facts. Fig.2 shows the convergence results after 20 generations of the genetic algorithm. The running time of the program is expressed as follows: "*Elapsed time is 0.340505 seconds*", so the running time of the program is very short,which can be ignored relative to the moving time of the carrying boards. The system can greatly shorten the time of saving and taking vehicles. For large stereo garage, the effect is more obvious.

## III. Configuration design of the monitoring interface of WINCC

In this three-in-one control platform, the configuration software WINCC need to get real-time data from MATLAB and PLC. WINCC can obtain the optimal scheduling scheme from MATLAB via the OPC protocol and get the status information of parking slots and the location information of carrying boards from PLC.

Monitoring interface is used to monitor the location of the carrying boards, the carrying boards being occupied or not, the status of parking slots and so on. In the monitoring interface as shown in Fig.3, there are "start" button, "stop" button, "parking" button, "taking" button, "auto" button that indicates automatic parking, "manual" button that indicates manual parking, operational direction button, "Pconform" button that indicates parking conform, "Tconform" button that indicates taking conform and so on. When completing parking, you need to press down the "Pconform" button to finish parking, when completing taking car, you need to press down the "Tconform" button to finish taking car.

Fig.3 Monitoring interface of WINCC



The monitoring interface is shown in Fig.3. When operating, after pressing down the “start” button, the system light will turn blue, then you can choose saving or taking car. When selecting saving car, only after pressing down the “parking” button can you select automatic parking or manual parking. To be sure, the operation of manual parking is used usually in special condition, such as repair. When selecting taking car, the next step is selecting the number of carrying board. When completing parking, press down the “Pconform” button, and when completing taking car, press down the “Tconform” button, so as to finish the operation of saving or taking car. In the program of PLC the operations of saving and taking car are interlocking. In Fig.3 the dots near the carrying boards represent limit switches. When the system fails, the system fault light will turn red. When the stereo garage is full, the FULL light will turn yellow. When the operation of saving or taking car is in progress, the operation light will turn red.

The movement of carrying board is achieved by C action in the monitoring interface. The carrying boards lift via updating the value of X and traverse via updating the value of Y. For instance, when the 3rd carrying board is on the top layer, let it move down to the first layer, the program of C action simply need to change the value of Y. On the top layer, Y=290, then gradually change the value of Y. Finally, Y=430, which realizes the 3st carrying board moving down to the first layer.

As is shown in Fig.3, when the 3rd carrying board is occupied, the photoelectric sensor on it will be triggered. After pressing the “Pconfirm” button, in the screen there will appear a car on the 3rd carrying board, which indicates that the carrying board is occupied.

## IV. Data communication between MATLAB and WINCC

### 4.1 OPC technology

OPC technology specification includes server and client. OPC server provides a set of standard COM interfaces, as long as the industrial automation software compliant with the OPC specification, it is no need to do any modification to consistently get access to all OPC server. OPC clients are generally designed and developed by the user, as long as comply with OPC data interface protocol, they can obtain data from the OPC server.

### 4.2 Realization of data communication

MATLAB as the OPC client and WINCC as the OPC server, they, as heterogeneous systems, achieve communication between each other via OPC technology.

WINCC provides OPC DA server, via which the real-time data from the client can be obtained. MATLAB connects with WINCC OPC server via the client program, and read the value of corresponding variable from OPC server. Specific steps is expressed as follows:

Step1: Install the OPC Foundation Core Components in the MATLAB via command *opcregister*;

Step2: Get the ServerID of OPC server via command *opcserverinfo*. In this system,ServerID= *OPCServer.WinCC.1*;

Step3: Configure DCOM in the OPC server and client, and obtain network access node name, to ensure that MATLAB and the OPC server can get connection;

Step4: Create corresponding variables in WINCC OPC server, built the OPC driver and set the relevant operating parameters, and ensure that OPC server is running when OPC client and OPC server communicates with each other;

Step5: Write the client program to achieve adding objects, groups and items and setting the property of groups and items. Achieve connection.

The main steps to write the client program is expressed as follows:

Step1: Create OPC data access server through the program statement *opcda ('localhost','OPCServer.WinCC.1')*;

Step2: Establish the connection through the command *connect*;

Step3: Add groups through the commend *addgroup*, and add items through the commend *additem*;

Step4: Set the property of groups, including *updaterate*, *Recordsacquiredfcncount*, *Recordstoacquire* and *datachangeFcn*;

Step5: Read data via *read* function, and white data via *Writeasync* function.

## V. Software design of the PLC control system

This paper uses the modularized programming method to design the program, which makes the program clear, easy to understand and easy to be modified, greatly reduces the complexity of the procedure and improves the versatility of the program. For the stereo garage with different size, you only need to make some appropriate changes to the program, such as increasing and decreasing some corresponding modules. After careful analysis, what can be found is that the programming of the carrying boards'movement on the same layer is similar and on the different layer is very different, so tiered processing approach should be used in the stereo garage. The same layer uses the same program module, which can greatly simplify the procedure.

5.1 Initialization of location of the carrying boards

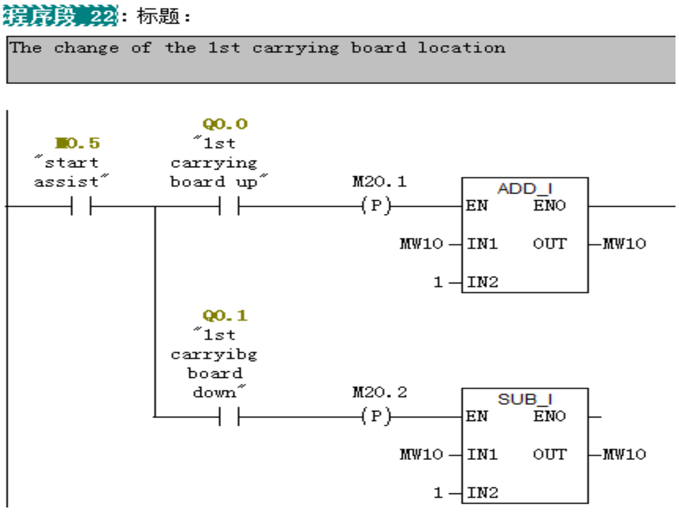
Fig.1 shows the initial location of the carrying boards. Assign the initial value to the storage site of the carrying boards' initial location. The 1st , 2nd and 3rd carrying board can only move vertically, so only what floor they are on is supposed to be recorded. The 4th and 5th carrying board can move vertically and horizontally, so what floor they are on and the column of them should to be recorded. The 6th and 7th carrying board can only move horizontally, so only the column of them is supposed to be recorded. Tab.2 shows the information of the carrying boards' location.

Tab.2 Assignment of the initial position of the carrying board

| Carrying board number | Storage location | Storage content | Initial value |
|---|---|---|---|
| 1 | MW10 | layer | 3 |
| 2 | MW12 | layer | 3 |
| 3 | MW14 | layer | 3 |
| 4 | MW16 | layer | 2 |
|  | MW18 | column | 1 |
| 5 | MW20 | layer | 2 |
|  | MW22 | column | 2 |
| 6 | MW24 | column | 1 |
| 7 | MW26 | column | 2 |

When these carrying boards move, the location information will change. When the carrying board move to other slots nearby, the corresponding data will plus or subtract 1. For instance, the 1st carrying board move to the next slot, the value in MW10 will plus or subtract 1. The segment program is shown in Fig.5.

Fig.5 Change of the carrying board’s location



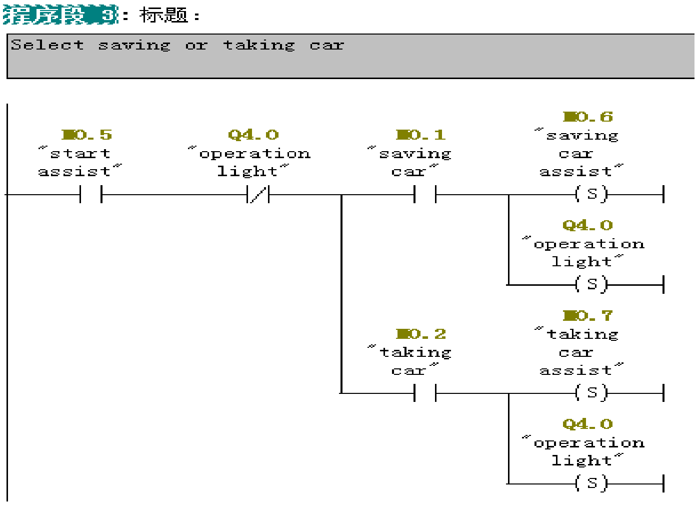
程序段 22：标题：

The change of the 1st carrying board location

### 5.2 Selection of saving or taking car

The input signal of PLC includes saving and taking car, and saving car includes automatic parking and manual parking. When selecting taking car, the number of the carrying board that you want to access should be chosen.

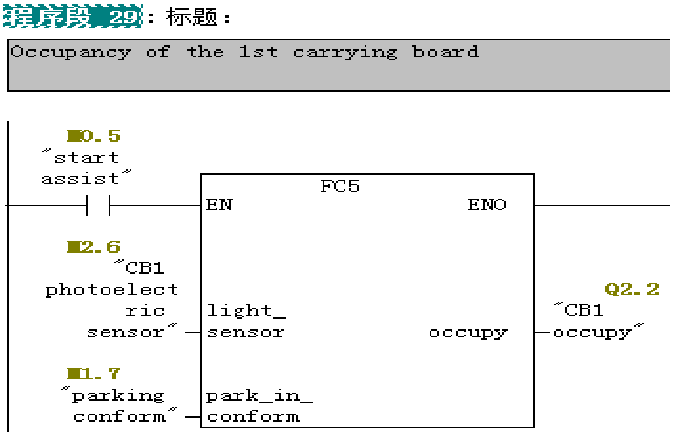
Fig.6 Program of selecting saving or taking car



### 5.3 Occupancy of the carrying boards

Before saving and taking car, the occupancy information of the carrying boards that is obtained by the photoelectric sensors should be obtained. This section of the program is written in FC module. Such as the occupancy of the 1st carrying board showing in Fig.7.

Fig.7 Occupancy of the 1st carrying board



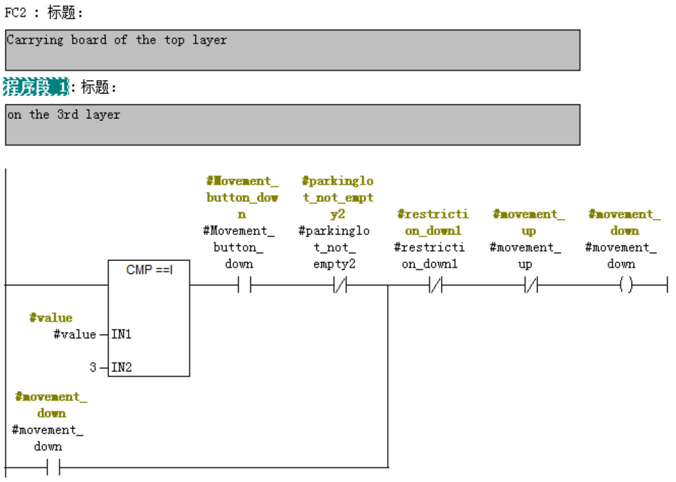
First, when a car gets on the carrying board, photoelectric sensors on which will receive the signal, then the contact *light_sensor* will close. After completing parking and pressing down the *Pconform* button, the input contact *park_in_conform* closes. Then the output contact *occupy* will be triggered, which means there is a car on this carrying board. When the car is taken away from the carrying board, the contact *light_sensor* will be disconnected, and the output contact *occupy* will also be disconnected,which means there is no car on this carrying board.

### 5.4 Parking

5.4.1 Manual parking

Manual parking is achieved by the single-step operation of the operator. The movement of the carrying boards subjects to two restrictions, the one is that the movement of the carrying boards must be in accordance with the provisions, for instance, the carrying boards on the top layer can only move up and down, and the another one is that the parking slot on the movement direction of the carrying board must be empty. This section of the program is written based on the two restrictions. The programming of the carrying boards on the same layer are similar, so each layer uses a FC module to write, totally it requires three FC modules.

Fig.8 Segment program of the FC module of the manual parking(Top layer)



FC2 : 标题:

Carrying board of the top layer

程序段 1: 标题:

on the 3rd layer

Fig.8 shows a program segment of the top layer FC2 module when the current location of carrying board is the 3rd layer. *value* indicates the location of the carrying boards, which can be MW10, MW12 and MW14. The normally open contact *Movement_button_down* indicates the moving down button. The normally closed contact *parkinglot_not_empty2* is used to ensure whether the parking slot on the moving direction of the carrying board is empty or not, if the parking slot is not empty, this contact will be disconnected. The normally closed contact *restriction_down1* indicates the restriction of moving down on the 2nd layer. *movement_down* indicates the action of moving down, and the normally closed contact *movement_up* indicates the action of moving up, which is used to interlock. When *value* equals 3, the moving down button is pressed down, the parking slot on the moving direction of the carrying board is empty and the limit swith is not triggered, the output contact *movement_down* will be triggered, and the carrying board will move down. The writing of the other program segments are similar.

### 5.4.2 Automatic parking

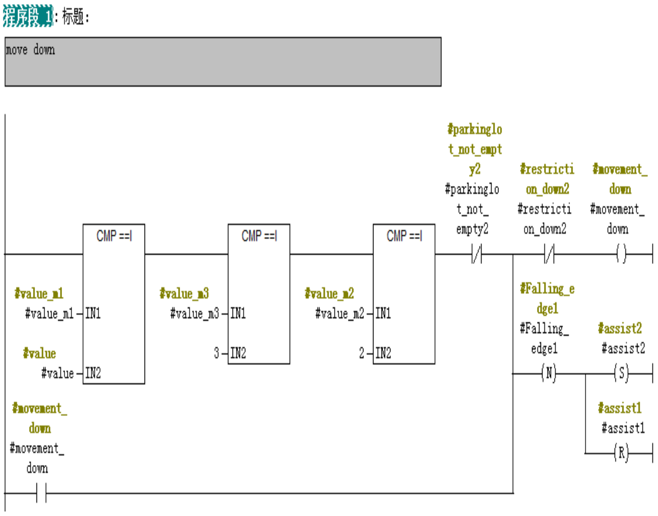
Automatic parking runs according to the optimal scheduling scheme obtained via MATLAB. One FC module needs to be written for each layer,totally three FC modules. There are seven carrying boards' number and corresponding movement, and Tab.3 shows their storage site in the PLC.

Tab.3 Storage site of the optimal scheduling scheme

| Carrying board number | Movement |
|---|---|
| MW30 | MW32 |
| MW34 | MW36 |
| MW38 | MW40 |
| MW42 | MW44 |
| MW46 | MW48 |
| MW50 | MW52 |
| MW54 | MW56 |

In the PLC, these carrying boards' number and movement are judged from top to bottom of Tab.3 in order. First,judge what's the carrying board's number stored in MW30, then conduct its corresponding movement according to the value stored in MW32, and then enter the next step. The last step is judging the carrying board's number stored in MW54 and the movement stored in MW56. Fig.9 shows segment program of the top layer FC module of the automatic parking.

Fig.9 Segment program of FC6 module of the auto parking



In Fig.9, *value_m1* indicates the carrying board's number, *value_m2* indicates movement, *value_m3* indicates the carrying board's location, *value* can be 1, 2 and 3, *value_m3* equaling 3 indicates that the carrying board is on the 3rd layer, and *value_m2* equaling 2 indicates moving down. The normally closed contact *parkinglot_not_empty2* is used to ensure whether the parking slot on the moving direction of the carrying board is empty or not. *restriction_down2* indicates the restriction of moving down on the 2nd layer. *Falling_edge1* indicates the falling edge. *assist1* indicates the executing condition of the current action, and *assist2* indicates the executing condition of the next step. *movement_down* indicates moving down.

The operation of taking car is similar to that of parking, so it's no need to say more.

The connection of WINCC and PLC, which can be achieved through the *SIMATIC S7 PROTOCOL SUITE* driver in simulation. This approach is simple, only need to let the variables in WINCC and PLC correspond. In the actual wiring, the connection of WINCC and PLC can be done through the communication bus RS-485.

## VI. Conclusion

In the three-in-one control platform based on OPC, MATLAB as the OPC client mainly do the complex calculation to obtain the optimal scheduling scheme, WINCC as the OPC sever is used to configure the monitoring interface, and PLC as the control system is used to control the stereo garage. Some features of the three-in-one control platform is expressed as follows: MATLAB does complex calculation, which can make up the deficience of PLC in complex computing; The platform obtains the optimal scheduling scheme through genetic algorithm, which is very reliable and greatly shorten the time of saving and taking cars; Use WINCC to configure the monitoring interface, which is simply operated and works safely and reliably; Structured programming of PLC improves the readability and versatility of the program. For the stereo garages with different size, simply need to be made some appropriate modifications, such as adding and deleting modules.

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