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Design of Control System for Kiwifruit Automatic Grading Machine

Xingjian Zuo, * Lijia Xu
College of Information Engineering and Technology, Sichuan Agricultural University
Yaan, Sichuan Province, 625014, China
* E-mail: lijiaxu13@163.com

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Abstract: The kiwifruit automatic grading machine is an important machine for postharvest processing of kiwifruit, and the control system ensures that the machine realizes intelligence. The control system for the kiwifruit automatic grading machine designed in this paper comprises a host computer and a slave microcontroller. The host computer provides a visual grading interface for the machine with a LabVIEW software, the slave microcontroller adopts an STC89C52 microcontroller as its core, and C language is used to write programs for controlling a position sensor module, push-pull type electromagnets, motor driving modules and a power supply for controlling the operation of the machine as well as the rise or descend of grading baffle plates. The ideal control effect is obtained through test, and the intelligent operation of the machine is realized.

Keywords: Kiwifruit automatic grading machine, Control system, STC89C52 microcontroller, C language.

1. Introduction

The kiwifruit automatic grading machine is an important intelligent grading machine, and the automatic grading can not only improve the grading efficiency, but also reduce the labor amount, and also increase the market value-added of products, thus grading plays an important role before kiwifruit enters the market. The control system thereof is the core of realizing automation. Kiwifruit grading is all along as a weak link of China's fruit production industry, at this stage the Chinese kiwifruit grading mainly includes manual grading and semi-mechanical grading, wherein the former has the obvious disadvantages that the grading standards are greatly affected by human factors, and the grading efficiency and grading accuracy cannot be compared with those in an automatic grading machine [1]; the latter is carried out only according to some characteristics. At present, few devices researched and developed at home and abroad are specially used for kiwifruit grading, the fully-automatic grading equipment machinery has a complex structure, the price is usually expensive [2-4], and the situation of kiwifruit grading directly leads to a big minus in quality. As one of the largest country in kiwifruit production, the research on how to improve the automatic grading level and increase the market competitiveness of Chinese kiwifruit has far-reaching significance. Therefore, the control system for the kiwifruit automatic grading machine designed in this paper adopts an STC89C52 microcontroller as the main control chip, which can accomplish various functions such as automatic running, automatic stopping and automatic control of grading baffle plates, and also provide a solution for the kiwifruit automatic grading machine.

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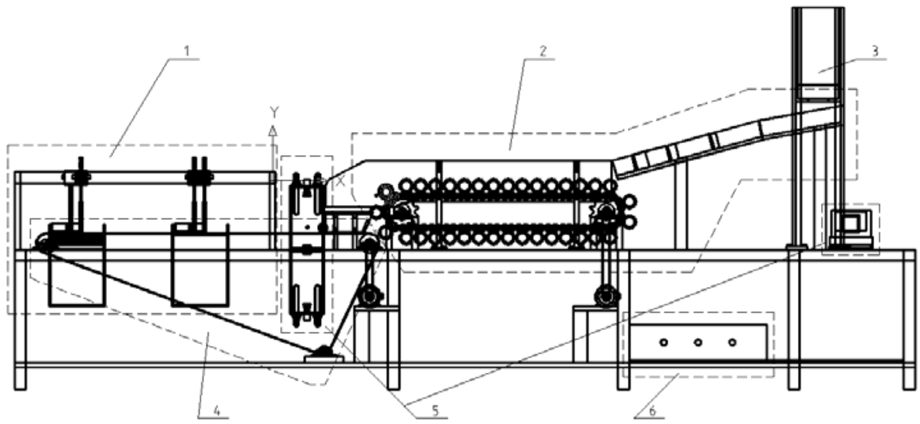
2. Hardware Structure of Control System

The kiwifruit automatic grading machine designed in this paper is shown in Fig. 1. A hardware system is composed of six parts: a storage box, a single-row positioning conveying system, an image acquisition system, a grading conveying system, a grading executive system and a control system; the storage box is mainly used for temporarily storing kiwifruits to be graded, the single-row positioning conveying system is used for separating the kiwifruits in the storage box into single rows of single kiwifruits at certain intervals for making preparations for image processing and grading of single kiwifruits; the image acquisition system is used for providing a stable light source for a CCD camera, so as to ensure the clear kiwifruit information extracted from the system and accurate kiwifruit grading; the grading conveying system is used for conveying the kiwifruits after image processing to specified grading boxes; the grading executive system is used for executing the signal of the control system for controlling the rise or descend of a grading baffle plate, so as to ensure the kiwifruits to enter into the corresponding grading boxes in the direction of the grading baffle plate; the control system is used for allowing the whole mechanical system to realize intelligent operation.



1-Grading executive system; 2-Single-line positioning system; 3-Material storage bin; 4-Grading conveying belt; 5-Image capture system; 6-Control system.

Fig. 1. Structure sketch of grading equipment.

3. Module Design Scheme of Control System

The control system adopts a host computer and an STC89C52 microcontroller as its core, a friendly man-machine interface for data acquisition, analysis, display and serial port control is designed by writing program with LabVIEW 8.6 software, and the exchange of data streams between subsystems of a grading system is further realized. First, the grading system is started through the man-machine interface, the initialization of the microcontroller and the connection between the microcontroller and the host computer are realized at the same time, and after receiving a kiwifruit positioning signal from a position sensor, the microcontroller transmits the kiwifruit positioning signal to the host computer through serial communication; cameras on the upper and lower sides of a transparent conveyer belt start collecting kiwifruit images, the images are transmitted to the host computer for storage trough a USB data line, then the labVIEW8.6 software invokes an MATLAB image processing program for image processing, so as to obtain quality characteristic parameters of kiwifruit, a BP neural network gives grades of kiwifruit according to the quality characteristic parameters, and then the host computer transmits the grading signals to the microcontroller through serial communication; the microcontroller controls the actions of corresponding grading baffle plates according to the grading signals for purpose of grading kiwifruits. The structure of the whole control system is shown in Fig. 2.

3.1. Position Sensor Module

The position sensor module is composed of an LE18S-A30NAD3 diffuse photoelectric switch and a supporting structure. The position sensor is positioned on the wall of a light box. After the grading system is started, the kiwifruits are conveyed through the single-row positioning conveying system and the conveyer belt, when the kiwifruits reach the vertical line of the camera, the light path of the position sensor is blocked, the kiwifruit positioning signal is transmitted to the microcontroller, and the microcontroller starts to communicate with the host computer. The circuit diagram of the position sensor is shown in Fig. 3.

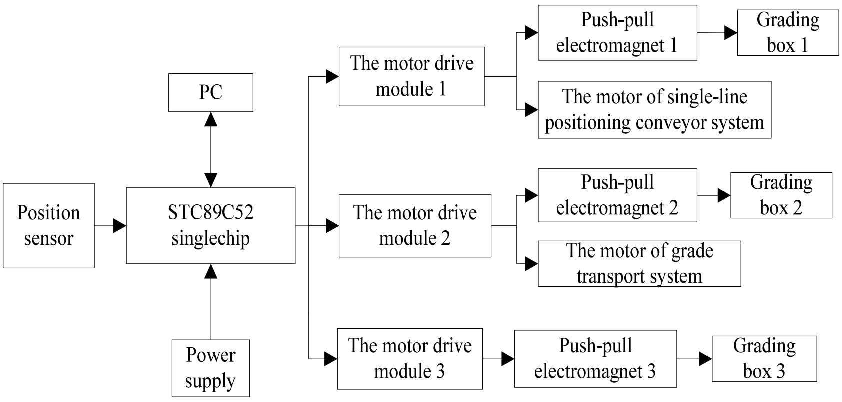


Fig. 2 The control block diagram showing the overall structure of the system.

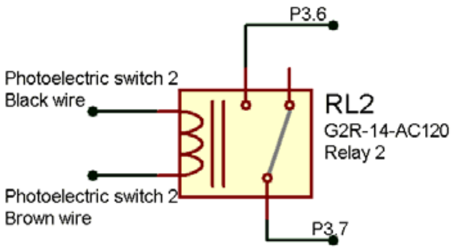


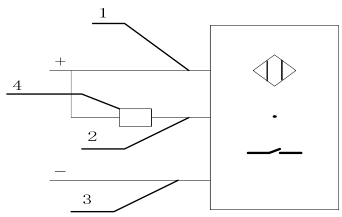
Fig. 3. Position sensor circuit.

3.1.1. Design of Position Sensor

The positioning information of kiwifruits on the transparent grading conveyor belt is monitored in real time, and determining the execution state of a grading program of the microcontroller according to the detection result is the inherent requirement of realizing the grading function of the system. During the running process of the hardware system, the microcontroller needs to monitor whether the kiwifruits are put in place in real time and transmits the signal to the host computer, thus the detection signal is only required to be changed when the kiwifruits reach the specified position, and a photoelectric switch is a commonly used device for realizing this function. In view of the blocking or reflection of a detected object to the light beam, the photoelectric switch is used for detecting whether an object exists through a gating circuit of a synchronous circuit. The object is not limited to metal, and all objects capable of reflecting light can be detected. The photoelectric switch transforms the input current into an optical signal emitted through an emitter, a receiver is used for detecting the target object according to the intensity of the light received or the presence or absence of light.

According to the demands of the system to the positioning of kiwifruits, the LE18S-A30NAD3 diffuse photoelectric switch is selected as the core of the position sensor, and the position sensor is a three-wire single-part position sensor with switching value output, which can detect whether an object exists according to the reflection of the detected object to infrared rays. The structure of the position sensor is shown in Fig. 4.

In Fig. 4, a brown wire is connected to a positive electrode of a power supply, a blue wire is connected to a negative electrode of the power supply, and a load is connected between a black wire and the brown wire. When the transmit path of an infrared emitter is blocked by the arrival kiwifruits, and light is reflected and received by an infrared receiver, the on-off state of the sensor is changed, and the load is powered on.



1-Blue wire; 2-Black wire; 3-Load; 4-Brown wire.

Fig. 4. Photoelectric switch diagram.

3.1.2. Electromagnetic Relay

The SRD-12VDC-SL-C electromagnetic relay is an automatic electric appliance, and used as an intermediate member for the position sensor and the microcontroller in the system. The operation characteristic curve and the structure of the electromagnetic relay are shown in Fig. 5 and Fig. 6 respectively.

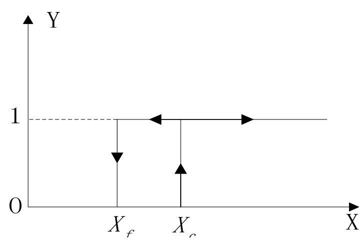
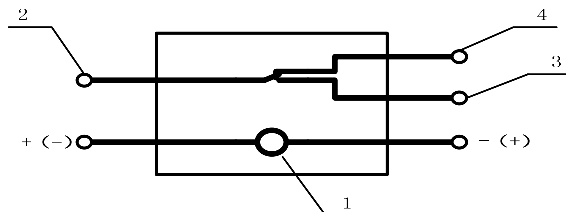


Fig. 5. The characteristic curve of the relay.



1-Coil; 2-COM port; 3-Normally closed contact;
4-Normally open contact.

Fig. 6. Relay structure diagram.

In Fig. 5, X represents the input voltage of a coil, Y represents the logic output quantity of a relay switch, X_f represents release voltage, and X_c represents pull-in voltage. When $X < X_f$, an armature does not move, the output quantity Y=0; when $X = X_c$, the armature gets absorbed, the switch is closed, the output quantity is changed from 0 to 1, and at the moment, normally closed contacts are opened, and normally open contacts are closed; the output quantity is continued to be increased, when $X > X_c$, the output quantity Y=1. When the output quantity is decreased, although the pull characteristic is lowered during the process of $X > X_f$, the suction force of the armature is still greater than the counterforce in the suction state, so the armature is not released, and the output quantity Y=1. When $X = X_f$, because the suction force is smaller than the counterforce, the armature is released, the output quantity is changed into 0 from 1, and the relay is restored.

In Fig. 6, two ends of the coil are connected to positive and negative terminals of the power supply, and the requirement of polarity is not required. A COM terminal is a common terminal, which can generally input signals which can be selectively output. The rest two contacts of a normally open contact and a normally closed contact are connected with the input end of a device required to be controlled.

3.1.3. Connection of Photoelectric Switch and Microcontroller

In the system, the photoelectric switch is in signal connection with the microcontroller through a relay, but not in direct physical contact with the microcontroller, and the connection between the both is shown in Fig. 7.

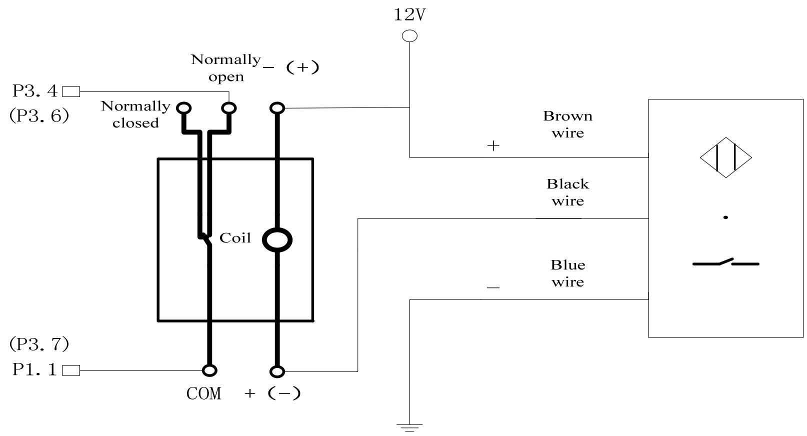


Fig. 7. Photoelectric switch with SCM physical connection diagram.

In Fig. 7, a brown wire of the photoelectric switch is connected to a positive electrode of a 12V power supply, and a blue wire is connected to power line ground; a black wire is connected to any contact of a relay coil, and then led to another contact of the relay coil from the brown wire; a P3.7 in a parallel port of the microcontroller is connected with the COM terminal, and a P3.6 is connected with a normally open contact of the relay. In the system, the position sensor is connected with the microcontroller. During the initialization of the microcontroller, the P3.7 is in high level, the P3.6 is in low level, when kiwifruits are conveyed to the position sensor module through the transparent grading conveyor belt, and the optical path of the photoelectric switch is blocked, the relay coil is powered on, the P3.6 is pulled to high level by the P3.7, when this state is detected through a program, the kiwifruit positioning information is sent to the host computer, and this process is defined as "kiwifruit positioning". The overall structure of the position sensor module is shown in Fig. 8.

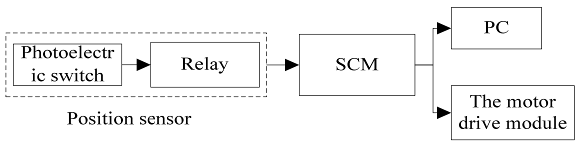


Fig. 8. The overall configuration diagram of the position sensor module.

3.2. Motors, Push-pull Type Electromagnets and Driving Modules

The system comprises two motors and three push-pull type electromagnets, wherein the motor 1 drives the single-row positioning conveying system to move, and the motor 2 drives the transparent grading conveyor belt to move; the push-pull type electromagnet 1 pulls a grading baffle plate 1 to rise or descend, the push-pull type electromagnet 2 pulls a grading baffle plate 2 to rise or descend, and the push-pull type electromagnet 3 pulls a grading baffle plate 3 to rise or descend. The microcontroller controls the working states of the push-pull type electromagnets through motor driving modules according to the received kiwifruit positioning signal, so as to realize the rise or descend of the grading baffle plates 1, 2 and 3 as well as the successful grading of kiwifruits.

3.2.1. Push-pull Type Electromagnets

The system adopts an inclined plane blocking type grading method, and the grading baffle plates are driven to move up and down by the push-pull type electromagnets. When the push-pull type electromagnet is powered off, the grading baffle plate is in the highest position, and kiwifruits can smoothly pass through the grading baffle plate; when the push-pull type electromagnet is in the suction state, the grading baffle plate is in the lowest position, and kiwifruits are blocked by the grading baffle plates, and slide into the corresponding grading boxes in the direction of the grading baffle plate. Based on this requirement, the push-pull type electromagnet with stroke of 3.5 cm and rated DC voltage of 12 V and with automatic resetting function is selected to drive the grading baffle plate.

3.2.2. L298N Motor Driving Modules

In the control system, three sets of motor driving modules [6] are used, a 5 V onboard power supply is enabled, and an external 5 V power supply is not used; a channel A of the motor driving module 1 is used for controlling the motor 1 for realizing the control of the single-row positioning conveying system; a channel B of the motor driving module 1 is used for the push-pull type electromagnet 1 for realizing the control of the grading baffle plate 1; a channel A of the motor driving module 2 is used for controlling the motor 2 for realizing the control of the transparent grading conveyor belt; a channel B of the motor driving module 2 is used for controlling the push-pull type electromagnet 2 for realizing the control of the grading baffle plate 2; a channel A of the motor driving module 3 is used for the push-pull type electromagnet 3 for realizing the control of the grading baffle plate 3. The p1.0, P1.7 and P1.2, the p1.0, P1.6 and P1.3, the p1.0, P1.5 and P2.1 as well as the p1.0, P2.2 and P1.4 and the p1.0 and P3.5 of the microcontroller are used as the logic output ends of the single-row positioning conveying device, the grading baffle plate 1, the grading baffle plate 2, the grading baffle plate 3 and the transparent grading conveyor belt respectively, during the working process, of the two logic input ends is only required to be set to “1”, the corresponding motor or push-pull type electromagnet is driven, and when different logic input ends are set to “1”, the rotating direction of the driven motors is different. The circuit connection is shown in Fig. 9.

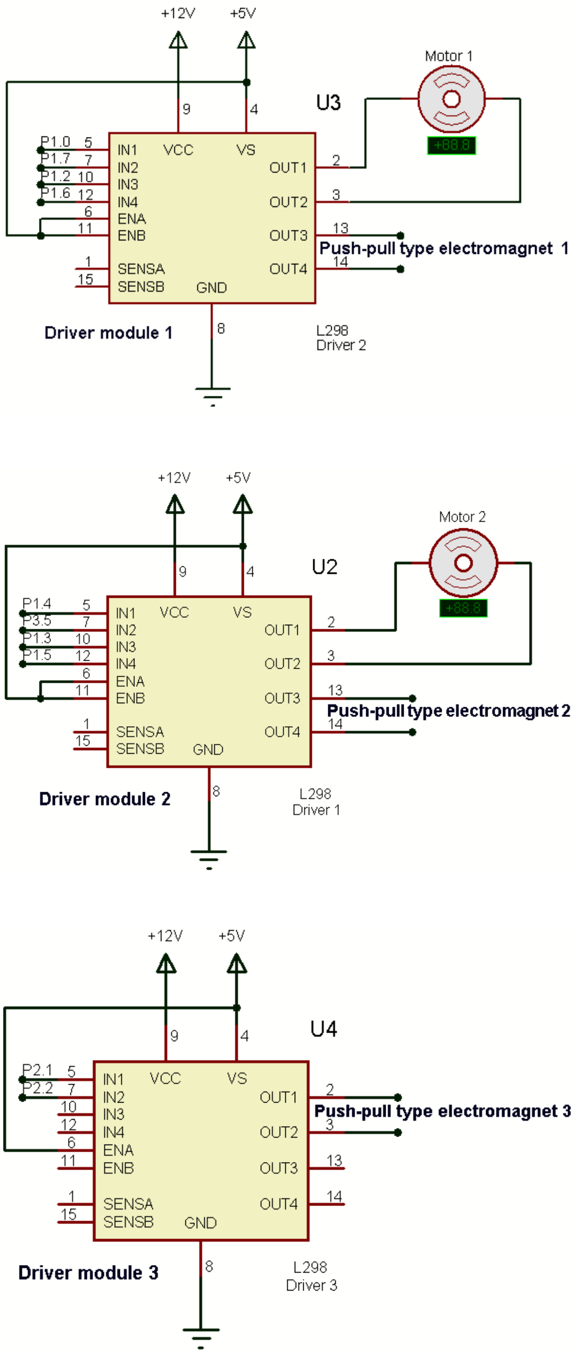


Fig. 9. A circuit diagram of motor and its drive modules.

3.3. Power Supply Module

The power supply of the slave microcontroller in the control system is completed through a USB power line communicated with the host computer, and the power supply of other parts is provided by an ST-122 type DC power supply. The power supply of lighting equipment is provided by a domestic 220 V AC power supply.

4. Serial Communication

4.1. Serial Port Setting

The baud rate of the serial port is set at 9600 bps. The control system is connected with the host computer through an RS232-TTL line, and instructions of the host computer are sent to the slave microcontroller through serial communication.

The instructions sent to the slave microcontroller from the host computer include start, suspend and stop instructions as well as four grading signals. Workers can send the start, suspend and stop instructions to the slave microcontroller from the man-machine interface according to the situation at the scene; after receiving the kiwifruit positioning information sent from the slave microcontroller, the host computer controls the camera to finish the work of image acquisition, the collected images are stored in the host computer, and after the images are processed through the host computer, the grading signal is sent to the slave microcontroller.

The instruction sent to the host computer from the slave microcontroller only includes a kiwifruit positioning signal. When receiving the signal, the host computer starts to control the camera for finishing image acquisition and storing and processing the images, and then sends the grading signal corresponding to the processing result to the slave microcontroller through a serial port. The working flow of the serial port is shown in Fig. 10. The codes for signal connection between the host computer and the slave microcontroller are shown in Table 1.

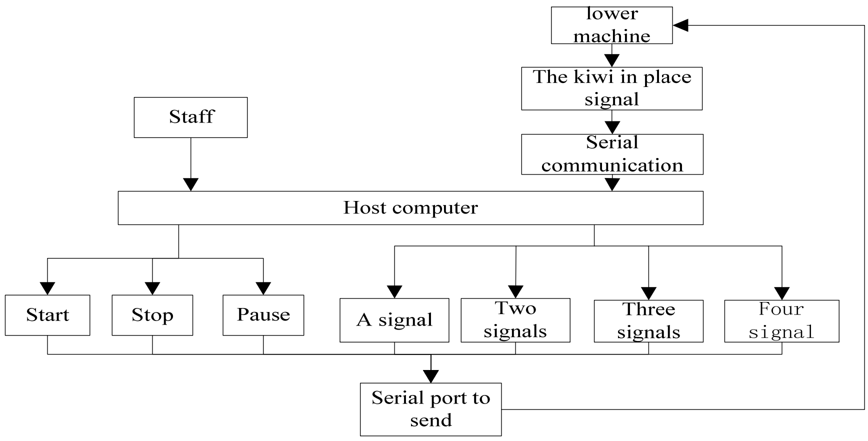


Fig. 10. Serial workflow.

Table 1. Signal connection of upper machine and lower machine.

Signal	The sending code
Kiwi in place	0X55
The first grade	0X31
The second grade	0X32
The third grade	0X33
The fourth grade	0X34
Start	0X30
Pause	0X35
Stop	0X36

5. Design of Software Structure of Host Computer

The software of the host computer mainly comprises an operation control part and an interaction part, wherein the operation control part comprises a starting device, a halt device and a stopping device, and used for implementing various functions of monitoring the grading progress, storing the grading results, performing error message warning and automatic processing, etc.; the interaction part comprises a landing device control system and a help system, and used for viewing the record files and reporting operation, setting the related parameters of equipment, changing passwords, etc. By adopting a graphic programming method [7], LabVIEW software with lots of functions can conveniently finish various operations of data acquisition, analysis and display, instrument control, measurement and test and industrial process simulation and control, and has good expansibility with other programming languages. Therefore, the software adopts labVIEW8.6 for programming, the image processing adopts MATLAB, and the operating system adopts Windows XP. Programming is carried out in the labVIEW8.6 according to the nodes and sequence. The flow chart of the software structure is shown in Fig. 11.

6. Experimental Test

In the system, aiming at the common kiwifruit lesion symptoms, the image approximate component features are obtained through wavelet transformation, the statistic features are extracted as the input parameters of BP neural network and the recognition of surface faults of kiwifruits is realized through training. The images obtained after the quantization encoding of approximate component of the third layer in wavelet transformation are compressed into a 100×100 dimension matrix, the median value, maximum value, minimum value and the difference between the maximum and minimum values in the matrix are extracted as the input parameters of the BP neural network for grading verification. The test results are shown in Table 2.

Table 2. Test results.

No	Defect or no defect	Desired output	Actual output	No	Defect or no defect	Desired output	Actual output
1.	Y	1	1.020484	41	Y	1	1.021066
2.	N	0	-0.05528	42	Y	1	0.820555
3.	Y	1	0.873705	43	Y	1	0.952468
4.	Y	1	1.024353	44	N	0	-0.07435
5.	N	0	-0.0635	45	Y	1	1.009494
6.	Y	1	1.018292	46	N	0	-0.05734
7.	Y	1	0.806659	47	Y	1	1.020465
8.	N	0	-0.06322	48	N	0	-0.06632
9.	N	0	-0.0635	49	N	0	-0.0227
10.	Y	1	0.108156	50	Y	1	1.021066
11.	N	0	0.129774	51	N	0	0.030735
12.	N	0	-0.05632	52	Y	1	0.424307
13.	N	0	-0.05734	53	Y	1	1.022928
14.	Y	1	1.022928	54	N	0	0.319255
15.	Y	1	1.020548	55	Y	1	1.021495
16.	Y	1	1.046718	56	N	0	-0.06567
17.	Y	1	1.021495	57	Y	1	1.020465
18.	Y	1	1.022086	58	N	0	-0.06739
19.	Y	1	1.024353	59	Y	1	0.806659
20.	N	0	-0.06567	60	N	0	-0.0635
21.	N	0	0.095904	61	Y	1	1.022473
22.	N	0	-0.02521	62	Y	1	0.873705
23.	N	0	-0.0436	63	Y	1	1.020142
24.	N	0	0.85327	64	N	0	0.095904
25.	N	0	-0.05794	65	Y	1	1.003501
26.	N	0	0.135731	66	Y	1	0.584572
27.	N	0	0.275656	67	N	0	-0.05678
28.	Y	1	1.010871	68	Y	1	1.022086
29.	N	0	-0.04454	69	N	0	1.303887
30.	Y	1	1.022633	70	Y	1	1.02661
31.	N	0	0.014773	71	N	0	-0.05933
32.	N	0	0.021012	72	Y	1	0.977687
33.	N	0	-0.04039	73	N	0	-0.03514
34.	Y	1	1.01912	74	Y	1	1.016991
35.	Y	1	0.890394	75	N	0	-0.06493
36.	Y	1	1.023574	76	N	0	-0.05672
37.	N	0	-0.0513	77	N	0	-0.04773
38.	Y	1	1.022517	78	Y	1	0.017276
39.	Y	1	1.003501	79	N	0	0.411776
40.	N	0	-0.03772	80	Y	1	0.667191

Note: Defective--Y, No defects--N

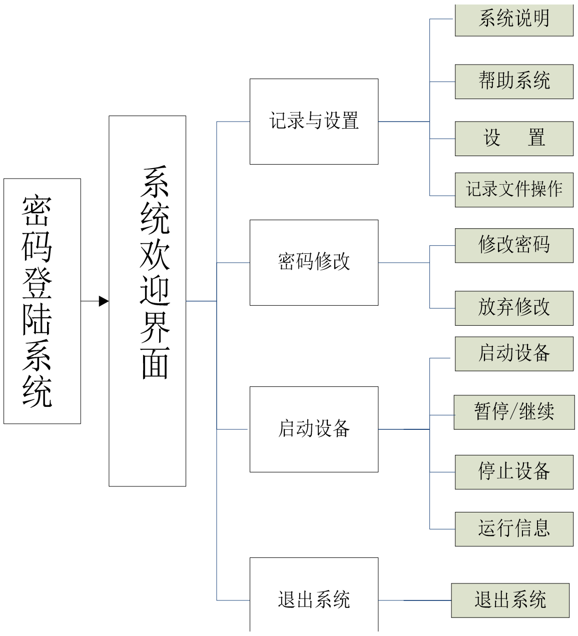


Fig. 11. PC software diagram.

7. Conclusions

With the comprehensive utilization of rich software and hardware resources of the STC89C52 microcontroller, the system realizes the intelligent control of the kiwifruit automatic grading machine through the visual monitoring running by being combined with the host computer. The position sensor module, push-pull type electromagnets and motor driving modules are combined organically, thus the operation control of the grading machine is realized through programming with C language. By adopting the modular design, the system has good expansibility and upgradeability. The experiments show that the design can realize the intelligent operation of the grading machine, but has deficiency in control accuracy, thus it needs to be improved and explored continuously in the practice.

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