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ELECTROTECHNICAL COMPLEXES AND SYSTEMS

Научная статья

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Ян Янь[1,2], Чичерин Иван Владимирович[1], Лицзюнь Чжао[2], Чанцзюань Лонг[1,2].

[1]Кузбасский государственный технический университет имени Т.Ф. Горбачева
[2]Школа интеллектуального производственного инжиниринга, Чунцинский университет искусств и наук

[*]E-mail: chiv.iap@kuzstu.ru

АВТОМАТИЗИРОВАННОЕ ПРОЕКТИРОВАНИЕ СИСТЕМЫ УПРАВЛЕНИЯ ПРИВОДОМ ДЛЯ СБОРА ЧАЯ

Аннотация.
Китай является крупным производителем чая. Сбор урожая чая в основном осуществляется путем ручного выщипывания и машинной резки. Сбор урожая вручную требует много времени и кропотливой работы, в то время как машинная резка не отличается избирательностью. Для решения этих проблем разработка автоматизированного устройства для сбора чая, которое отличается избирательностью, эффективностью и низким уровнем повреждений, стало неизбежным выбором для содействия устойчивому развитию чайной промышленности. Для достижения автоматизации была внедрена система автоматического управления сбором чая. Эта конструкция основана на трехосевой системе управления с использованием ПЛК (программируемого логического контроллера). В нем рассматриваются такие аспекты, как выбор и согласование параметров серводвигателя, разработка блок-схем управления движением, разработка и внедрение программ ПЛК, а также проектирование интерфейсов взаимодействия человека и машины. Контроллер ПЛК Siemens S7-1200 используется для обеспечения одноосевого и многоосевого управления трехосевым механизмом. Управление по одной оси включает в себя режим перемещения рабочего места, режим относительного перемещения и режим абсолютного перемещения по осям X, Y и Z соответственно. Режим координированного управления по трем осям включает в себя режим абсолютного перемещения и режим относительного перемещения. Функция мониторинга состояния реализована через человеко-машинный интерфейс (HMI). В ходе экспериментальных испытаний системы было доказано, что разработанная трехосевая система сервоуправления может соответствовать требованиям управления движением.

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1. Introduction

Tea, which is rich in various nutrients such as tea polyphenols, aromatic oils, minerals, proteins, and vitamins, offers health benefits including blood pressure reduction, lipid lowering, and immune enhancement[1]. Additionally, it provides effects such as refreshing the mind, dispelling oil and relieving fatigue, making it one of the "three major non-alcoholic beverages" in the world today[2]. Tea tasting has become an indispensable part of people's lives. China, as the birthplace of tea plants and a major producer of tea[3], currently employs two primary methods for tea leaf harvesting in its tea gardens: manual plucking and mechanical harvesting using tea-plucking machines. Manual tea plucking is an arduous and time-consuming task[4]. In the context of ongoing urbanization and an

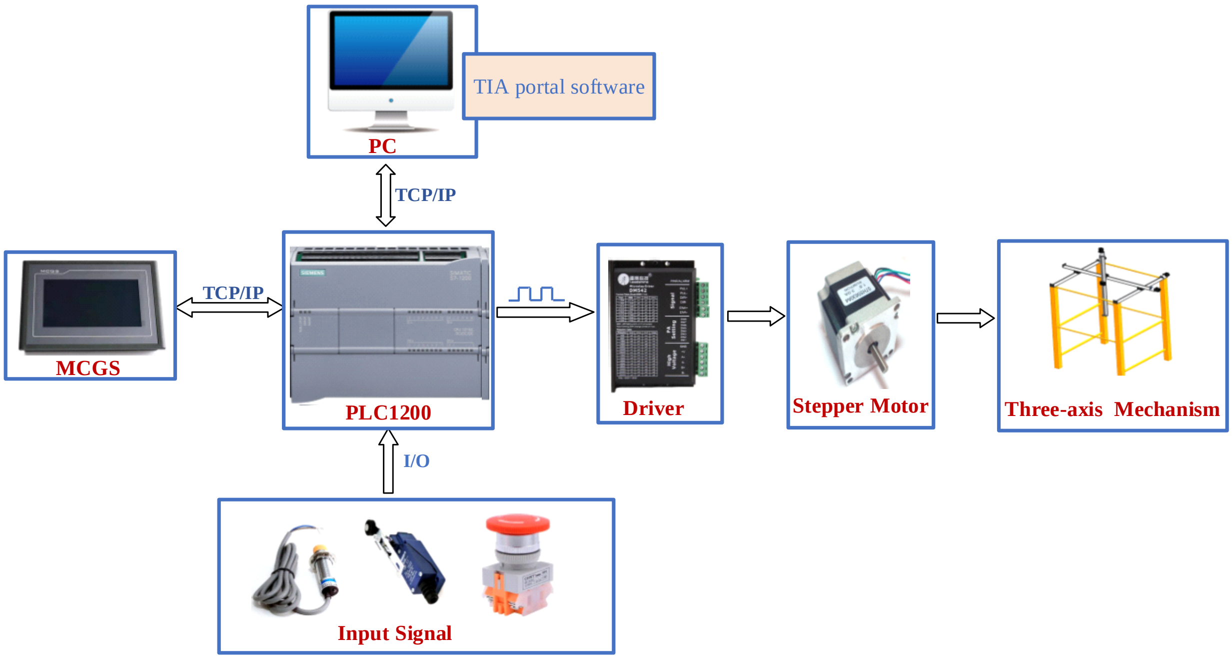


Fig.1.System architecture

aging population, an increasing number of young people are reluctant to engage in tea plucking, leading to a labor force primarily consisting of women and older adults. This labor shortage has resulted in situations where tea leaves in some areas are either not picked or harvested untimely. Compared to manual plucking, using tea-plucking machines can alleviate the pressure of labor shortages and significantly enhance the efficiency of tea leaf harvesting. However, the mature tea-plucking machines currently available in the market adopt a method of cutting tea tree tips for harvesting, leading to a "one-size-fits-all" approach[5, 6]. The quality of fresh leaves harvested using this method is notably inferior to that of manually picked leaves, as it collects both new and old leaves while also incorporating a substantial amount of tea stems and substandard leaves. Consequently, this results in a significant workload for subsequent screening and sorting. Therefore, to address the issues of inadequate labor and high costs in the harvest of high-quality tea, as well as the limitations of existing conventional tea harvesting machinery, it is necessary to research automated tea harvesting equipment as a replacement for manual labor[7]. Automation machine includes three main components that are machine vision, servomechanism, and chassis. The paper focuses on design and research on mechanical structure of tea plucking[8]. This study mainly considers the automation design of a three-axis servo mechanism.

2. Design architecture

The agricultural mechanization industry has been experiencing an increasing demand for higher quality, more efficient, and automated machinery[9, 10]. Many industrial controllers have also been widely used in the agricultural sector. PLC, as an essential industrial automation control device, plays an indispensable role in modern industrial production[11, 12]. The three-axis linkage control system has various control methods such as relay control, computer control, and PLC control. Due to the programmable, expandable, real-time, easy to maintain, and strong programmability features of PLC[13, 14], the Siemens S7-1200 PLC is chosen as the controller for this design. The Siemens S7-1200 [15]can perform tasks such as logic control, data processing, monitoring, upper computer connection, and network communication. The CPU model of this PLC is CPU 1215C DC/DC/DC, which has 16 digital input/output ports, analog I/O ports, and an integrated PROFINET interface. The CPU can be expanded with 8 signal modules on the right side and can connect up to 3 communication modules on the left side. Additionally, the S7-1200 CPU 1215C DC/DC/DC facilitates user development and maintenance and allows communication with the HMI[16]. HMI is designed based on the object-oriented principle to guide and assist operators in monitoring and managing the field according to their work requirements. In this system's human-machine interaction terminal, the MCGS touchscreen, model TPC1071Gi, is used. This touchscreen is used in conjunction with the PLC and is connected via Ethernet, enabling real-time monitoring and control of the entire system. TIA (Totally Integrated Automation) Portal software[17, 18], developed by Siemens, is an engineering framework that offers an integrated approach to automation needs. It combines functionalities for the configuration, programming, test, and diagnostics of different automation systems in a single interface. It also covers all digital and analogue I/O systems, networked systems such as PROFIBUS & PROFINET[19, 20], PLCs, HMIs, and drives. This design uses the Profinet protocol for communication between the PLC controller, PC computer, and MCGS, transmitting data through Ethernet. A stepper motor is chosen as the power source. The number of pulses and current size required for each rotation of the motor are set through the driver, and high-speed pulses are emitted by the PLC1200 for positioning control. This project uses a 57 series two-phase stepper motor with a

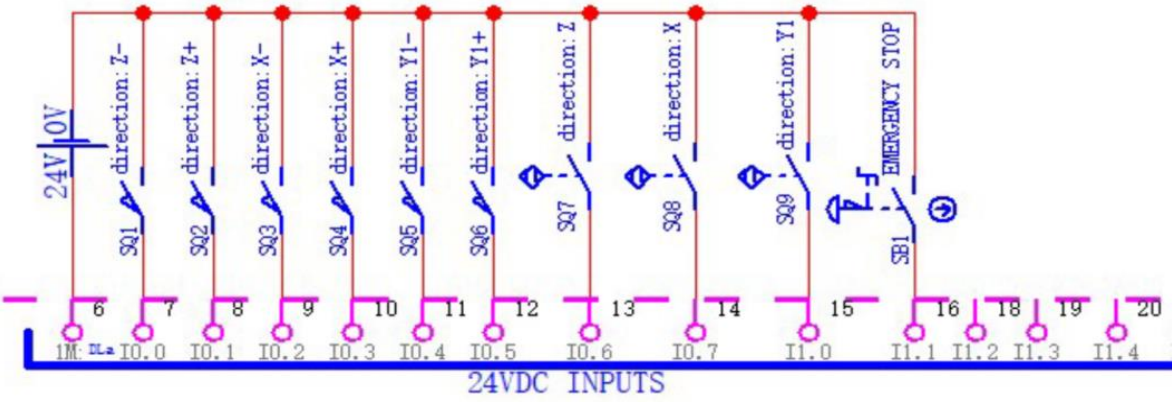


Fig.2. input signal of PLC

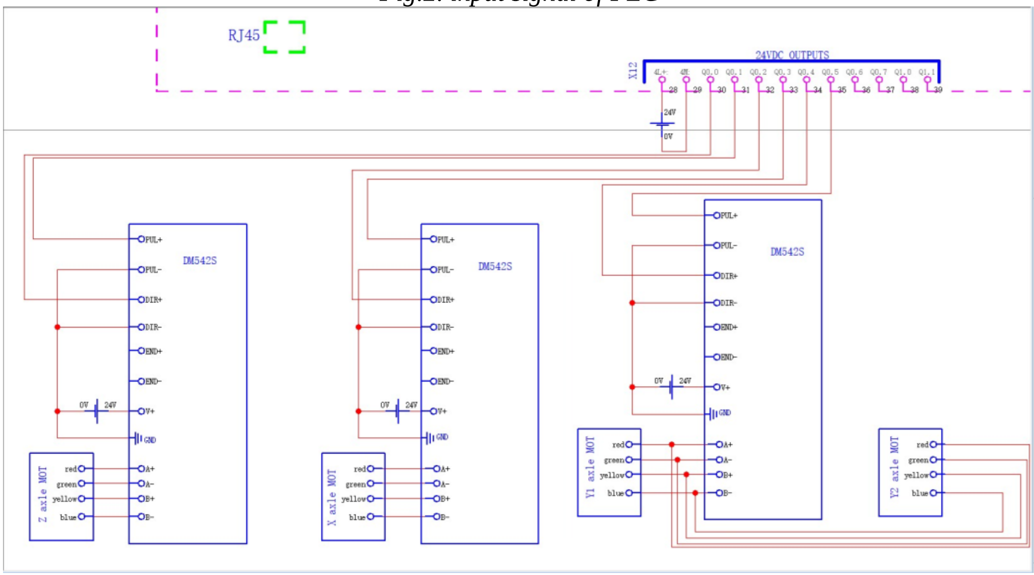


Fig.3.input signal of PLC

step angle of 1.8°, a torque of 2.3N, and a rated current of 3.0A. The model of the stepper motor driver is M542. The subdivision setting of the stepper motor driver selects a subdivision number of 4800 pulses/rotation; for the current setting, the average current is 2.8A and the peak current is 2.9A. The movement in the X, Y, and Z directions within the space is achieved through a three-axis linkage module. This structure is a typical series mechanism, with the motor providing power and the power being transmitted through ball screws, etc. The driven moving component slides along the guide rail for linear motion. With three-axis linkage, any target point within the working space can be reached. Limit switches and proximity switches are used for motion control limiting and homing position locating respectively. The design architecture is shown in the Fig.1.

3. Implementation

3.1 I/O address assignment

The input ports I0.0 to I0.5 correspond to the limit switches of each axis. They are all equipped with roller-style mechanical limit switches to prevent the motion object from exceeding the working range. The input ports I0.6 to I1.0 are connected to the home switches of three axes. They use photoelectric proximity switches installed at the home positions of each axis. When the motion object is at the home position, it sends a signal to the PLC for easy reading of the position of the motion object and better control. I1.1 is connected to a normally open mechanical emergency stop button. After pressing the button, it needs to be manually rotated for reset to ensure safety, as shown in Fig. 2. The output ports Q0.0 to Q0.5 are connected to the PUL (pulse output) and DIR (direction pulse) of the driver. The PLC sends pulses to the driver, and the driver controls the stepper motor accordingly, as shown in Fig.3.

3.2 Communication protocol

After selecting the option to allow PUT/GET communication access from remote objects in the PLC connection mechanism of the TIA Portal software, the PLC can communicate with MCGS. This is because before the communication between the PLC and the upper computer, it is necessary to allow PUT/GET communication access from remote objects. This is because the communication between the PLC and the upper computer is implemented through a network protocol, and PUT/GET communication is a commonly used network protocol. PUT/GET communication refers to the way of communication using the PUT and GET methods of the HTTP protocol. The PUT method is used for uploading data, and the GET method is used for retrieving data. As a network device, the PLC needs to support the PUT/GET protocol to realize communi-

Table1 IP Address Setting

Device	IP Address
S7-1200	192.168.0.1
PC	192.168.0.2
MCGS	192.168.0.3

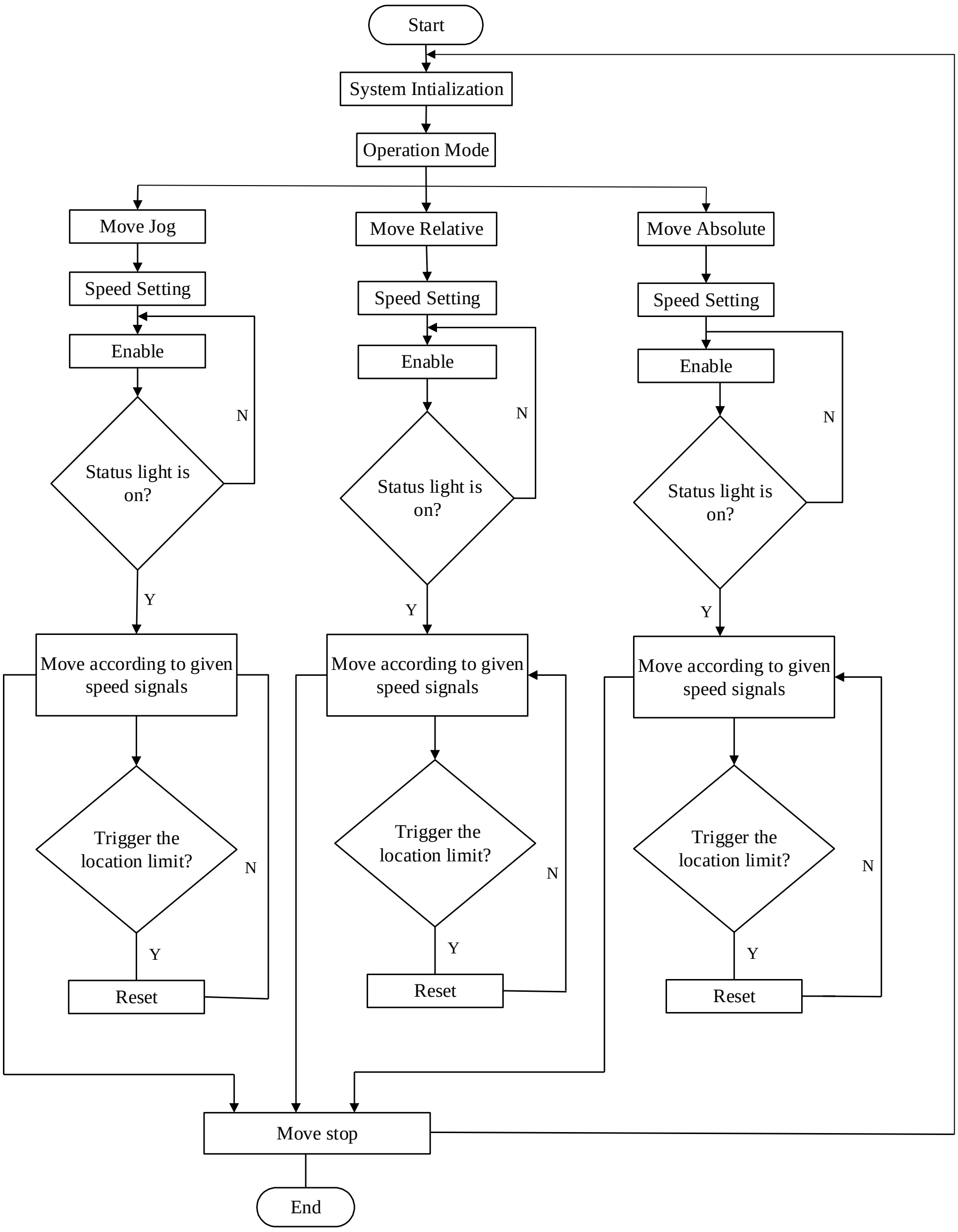


Fig. 4. Flowchart of program

cation with the upper computer. The touch screen communicates with the personal computer and S7-1200 using Ethernet, and it is necessary to coordinate the control signals between the devices. Therefore, it is necessary to set up the physical connection and IP address of the local area network. In the touch screen software, the remote IP is set as the address of the S7-1200 PLC, and the local IP is set as the address of the touch screen. It is important to ensure that the IP addresses are set within the same network segment to avoid duplication and affect communication.

3.3 The overall software design

The operation program of three-axis servo mechanism is designed into three working modes, namely, move jog, move relative, move absolute. After the system is powered on, the MCGS displays the interface and then enters the main screen. In the screen, operators can choose in to sub-screens. Under the debugging interface, the operation mode of x、y、z axis can be selected in sequence. It realizes forward, backward, back to the origin, positioning movement. When the servo mechanism moves to the localization limit point, the system can reset itself and reverse operation can be performed. When returning to the origin or positioning

a. Main screen

b. Mode screen

Fig. 5. Interface of HMI

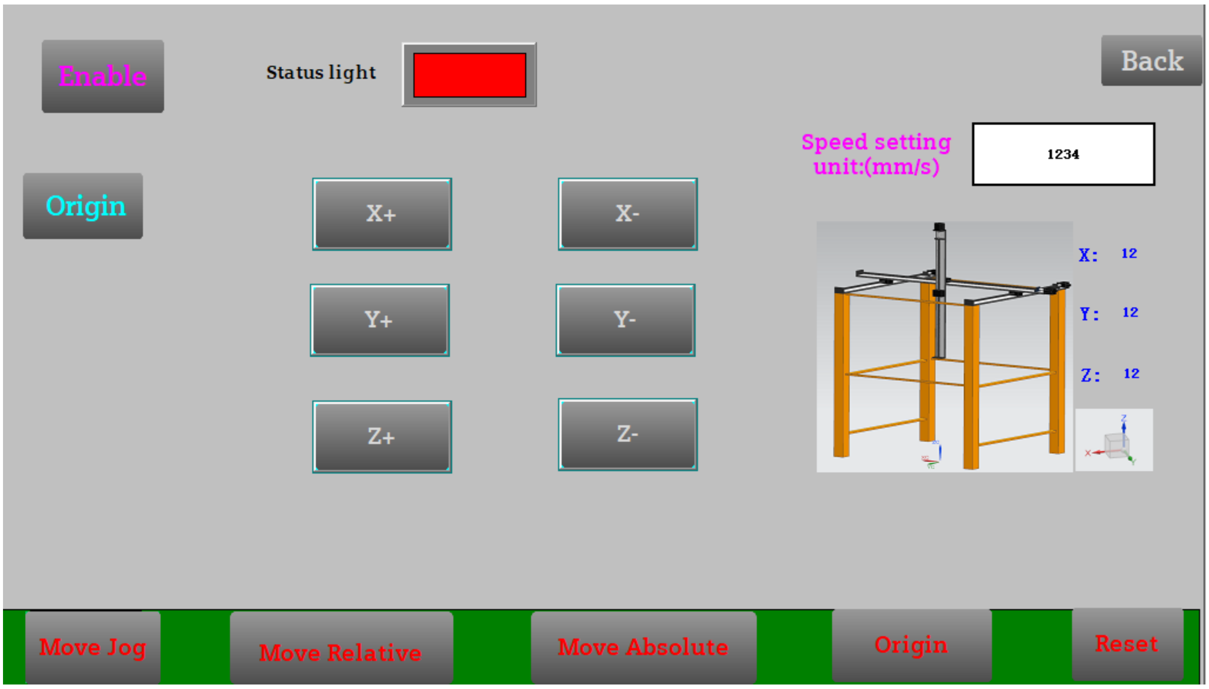
movement, a signal will be given and return to run. The main control flowchart is shown in Fig.4.

3.4 HMI Design

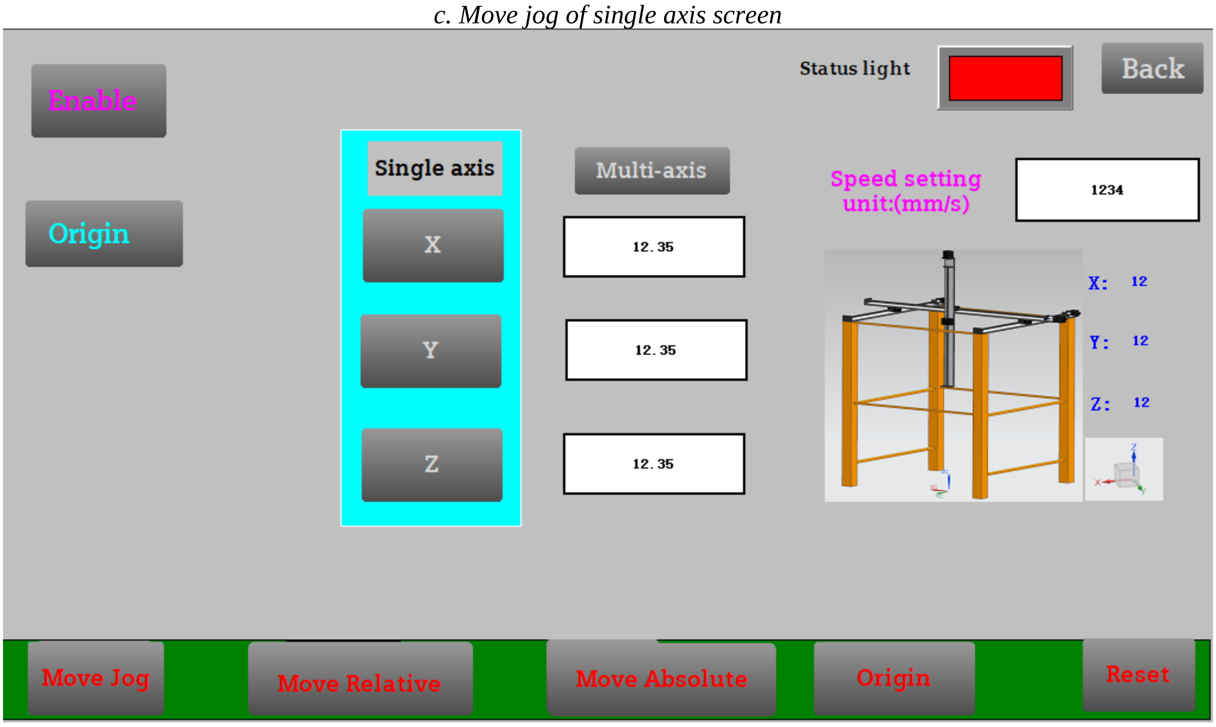
Human Machine Interface is a device for the exchange of information between operators and machines, which is used to realize the dialogue and interaction between operators and computer control system. In this system, MCGS touch screen is used as the configuration monitoring device, and MCGS embedded version is used to configure the touch screen. The system mainly includes 5 interfaces, which are the main screen, move mode screen, move jog screen, move relative and move absolute screen, origin screen. Under the screen of operation mode, the user can choose single axis or three-axis coordinated operation, and the screen displays the current running state at the same time. Interface of HMI panel program is shown in Fig.5.

4.Conclusion

The study is based on the Siemens S7-1200 PLC controller and has completed the design of the three-axis servo mechanism control system for plucking tea. This design allows the mechanism to achieve independent control in the x, y, and z directions, as well as three-axis coordinated control, laying the foundation for the next step of integrating machine vision to realize the location of tea shoots.



c. Move jog of single axis screen



d. Move relative and move absolute of multi-axis screen

Fig. 5 Continued

СПИСОК ЛИТЕРАТУРЫ

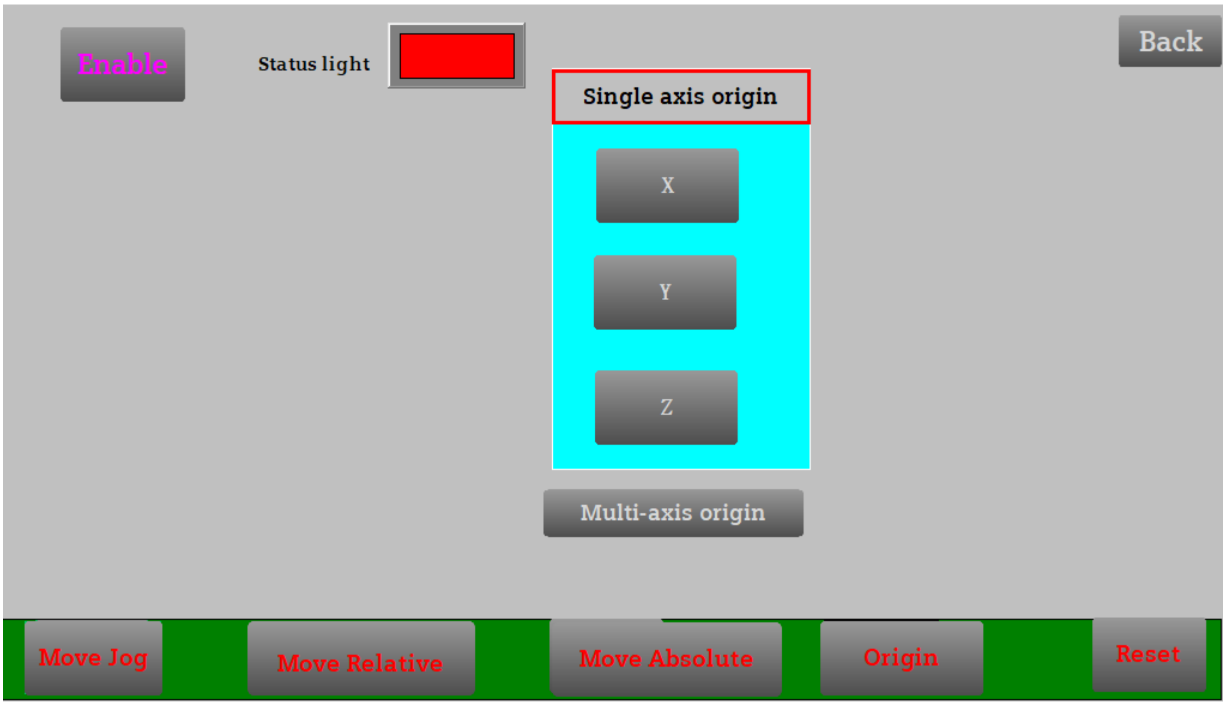
[1] H. Wang, J. Gu, and M. Wang, "A review on the application of computer vision and machine learning in the tea industry," *Frontiers in Sustainable Food Systems*, vol. 7, 2023, doi: 10.3389/fsufs.2023.1172543.

[2] Y. Wu *et al.*, "An improved YOLOv7 network using RGB-D multi-modal feature fusion for tea shoots detection," *Computers and Electronics in Agriculture*, vol. 216, 2024, doi: 10.1016/j.compag.2023.108541.

[3] R. Zhao *et al.*, "IMVTS: A Detection Model for Multi-Varieties of Famous Tea Sprouts Based on Deep Learning," *Horticulturae*, vol. 9, no. 7, 2023, doi: 10.3390/horticulturae9070819.

[4] Y.-L. Lai, P.-L. Chen, and P.-L. Yen, "A human-robot cooperative vehicle for tea plucking," in *2020 7th International Conference on Control, Decision and Information Technologies (CoDIT)*, 2020, vol. 1: IEEE, pp. 217-222.

[5] T. Yiping, H. Wangming, H. Anguo, and W. Weiyang, "Design and Experiment of Intelligentized Tea-plucking Machine for Human Riding Based on Machine Vision," *Transactions of the Chinese Society for Agricultural Machinery*, 2016.



f. Origin of single and multi-axis screen

Fig. 5 Continued

[6] B. Li, H. Zhu, L. Fang, Y. Zhu, and S. F-ang, "Design and experimentation of craw-ler tea harvesting machine," *Journal of the Chinese Institute of Engineers*, vol. 47, no. 5, pp. 482-491, 2024, doi: 10.1080/02533839.2024.2346485.

[7] Y. Zhu *et al.*, "Deviation Tolerance Performance Evaluation and Experiment of plucking End Effector for Famous Tea," *Agriculture*, vol. 11, no. 2, 2021, doi: 10.3390/agriculture11020128.

[8] Y. Yang, I. V. Chicherin, L. Zhao, and C. Long, "Design and Research on Servomechanism of Tea Plucking," *Vestnik of Kuzbass State Technical University*, no. 1, pp. 14-22, 2024, doi: 10.26730/1999-4125-2024-1-14-22.

[9] T. Wang, B. Chen, Z. Zhang, H. Li, and M. Zhang, "Applications of machine vision in agricultural robot navigation: A review," *Computers and Electronics in Agriculture*, vol. 198, 2022, doi: 10.1016/j.compag.2022.107085.

[10] X. Hua *et al.*, "A Review of Target Recognition Technology for Fruit plucking Robots: From Digital Image Processing to Deep Learning," *Applied Sciences*, vol. 13, no. 7, 2023, doi: 10.3390/app13074160.

[11] K. S. Kiangala and Z. Wang, "An Industry 4.0 approach to develop auto parameter configuration of a bottling process in a small to medium scale industry using PLC and SCADA," *Procedia Manufacturing*, vol. 35, pp. 725-730, 2019.

[12] R. Langmann and M. Stiller, "The PLC as a Smart Service in Industry 4.0 Production Systems," *Applied Sciences*, vol. 9, no. 18, 2019, doi: 10.3390/app9183815.

[13] J. Hajda, R. Jakuszewski, and S. Ogonowski, "Security Challenges in Industry 4.0 PLC Systems," *Applied Sciences*, vol. 11, no. 21, 2021, doi: 10.3390/app11219785.

[14] M. Lee, J. W. Kim, Y. Mo, and A. D. Walker, "A review of professional learning community (PLC) instruments," *Journal of Educational Administration*, vol. 60, no. 3, pp. 262-287, 2022, doi: 10.1108/jea-03-2021-0060.

[15] H. Salih, H. Abdelwahab, and A. Abdallah, "Automation design for a syrup production line using Siemens PLC S7-1200 and TIA Portal software," in *International Conference on Communication*, 2017.

[16] B. Hasan, S. U. H. Mohani, S. S. Hussain, S. Yasin, and O. Saeed, "Implementation of Supervisory Control and Data Acquisition - SCADA on a PLC and VFD Controlled Digital Mixing Plant Using TIA Portal," in *2019 4th International Conference on Emerging Trends in Engineering, Sciences and Technology (ICEEST)*, 2019.

[17] H. He, Y. Long, and W. Yu, "Design and Simulation of Elevator Emergency System Based on TIA Portal V15.1," *Journal of Physics: Conference Series*, vol. 1802, no. 4, p. 042089 (5pp), 2021.

[18] K. J. Alaameri, A. J. Ramadhan, A. Fatlawi, and Z. S. Idan, "Design of a new sorting colors system based on PLC, TIA portal, and factory I/O programs," *Open Engineering*, vol. 14, no. 1, 2024, doi: 10.1515/eng-2022-0547.

[19] G. Gabor and G. Livint, "Solution for Monitoring and Remote Control Based on Modbus RTU and S7-1200 PLC," presented at the 2021 International Conference on Electromechanical and Energy Systems (SIELMEN), 2021.

[20] S. Vadi, R. Bayindir, Y. Toplar, and I. Colak, "Induction motor control system with a Programmable Logic Controller (PLC) and Profibus communication for industrial plants - An experimental setup," *ISA Trans*, vol. 122, pp. 459-471, Mar 2022, doi: 10.1016/j.isatra.2021.04.019.

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Об авторах:
Ян Янь, Кузбасский государственный технический университет имени Т.Ф. Горбачева, (650000, Российская Федерация, г. Кемерово, ул. Весенняя, 28), Школа интеллектуального производственного инжиниринга, Чунцинский университет искусств и наук, (Чунцин, 402160, Китай)
Чичерин Иван Владимирович, Кузбасский государственный технический университет имени Т.Ф. Горбачева, (650000, Российская Федерация, г. Кемерово, ул. Весенняя, 28), e-mail: chiv.iap@kuzstu.ru
Лицзюнь Чжао, Школа интеллектуального производственного инжиниринга, Чунцинский университет искусств и наук, (Чунцин, 402160, Китай)
Чанцзюань Лонг, Кузбасский государственный технический университет имени Т.Ф. Горбачева, (650000, Российская Федерация, г. Кемерово, ул. Весенняя, 28), Школа интеллектуального производственного инжиниринга, Чунцинский университет искусств и наук, (Чунцин, 402160, Китай)

Заявленный вклад авторов:
Ян Янь – постановка исследовательской задачи; научный менеджмент; обзор соответствующей литературы; концептуализация исследования; написание текста, сбор и анализ данных; обзор соответствующей литературы; выводы; написание текста.
Чичерин И.В., – постановка исследовательской задачи; научный менеджмент; обзор соответствующей литературы; концептуализация исследования; написание текста, сбор и анализ данных; обзор соответствующей литературы; выводы; написание текста.
Лицзюнь Чжао – постановка исследовательской задачи; научный менеджмент; обзор соответствующей литературы; концептуализация исследования; написание текста, сбор и анализ данных; обзор соответствующей литературы; выводы; написание текста.
Чанцзюань Лонг – постановка исследовательской задачи; научный менеджмент; обзор соответствующей литературы; концептуализация исследования; написание текста, сбор и анализ данных; обзор соответствующей литературы; выводы; написание текста.

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Yan Yang [1,2], Ivan V. Chicherin[1], Lijun Zhao[2], Chanjuan Long [1,2].

[1]T.F. Gorbachev Kuzbass State Technical University,
[2]School of Intelligent Manufacturing Engineering, Chongqing University of Arts and Sciences

[*]E-mail: chiv.iap@kuzstu.ru

AUTOMATION DESIGN OF THE DRIVE CONTROL SYSTEM FOR PLUCKING TEA

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Abstract.
China is a major producer of tea. Tea harvesting mainly relies on manual plucking and machine cutting. Manual plucking is time-consuming and laborious, while machine cutting lacks selectivity. To address these issues, the development of an automated tea harvesting device that is selective, efficient, and has a low damage rate has become an inevitable choice for promoting the sustainable development of the tea industry. In order to achieve automation, a tea harvesting automatic control system is implemented. This design is based on a three-axis servo control system using a PLC (Programmable Logic Controller). It explores aspects such as the selection and matching of servo motor parameters, the design of motion control flowcharts, the development and implementation of PLC programs, and the design of human-machine interaction interfaces. The Siemens S7-1200 PLC controller is used to achieve single-axis control and multi-axis control

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of the three-axis mechanism. Single-axis control includes job movement mode, relative movement mode, and absolute movement mode for the X-axis, Y-axis, and Z-axis respectively. The three-axis coordinated control mode includes absolute movement mode and relative movement mode. The status monitoring function is implemented through the human-machine interface (HMI). Through experimental testing of the system, it has been proven that the designed three-axis servo control system can meet the requirements of motion control.

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REFERENCES

[1] H. Wang, J. Gu, and M. Wang, "A review on the application of computer vision and machine learning in the tea industry," *Frontiers in Sustainable Food Systems,* vol. 7, 2023, doi: 10.3389/fsufs.2023.1172543.

[2] Y. Wu *et al.*, "An improved YOLOv7 network using RGB-D multi-modal feature fusion for tea shoots detection," *Computers and Electronics in Agriculture,* vol. 216, 2024, doi: 10.1016/j.compag.2023.108541.

[3] R. Zhao *et al.*, "IMVTS: A Detection Model for Multi-Varieties of Famous Tea Sprouts Based on Deep Learning," *Horticulturae*, vol. 9, no. 7, 2023, doi: 10.3390/horticulturae9070819.

[4] Y.-L. Lai, P.-L. Chen, and P.-L. Yen, "A human-robot cooperative vehicle for tea plucking," in *2020 7th International Conference on Control, Decision and Information Technologies (CoDIT)*, 2020, vol. 1: IEEE, pp. 217-222.

[5] T. Yiping, H. Wangming, H. Anguo, and W. Weiyang, "Design and Experiment of Intelligentized Tea-plucking Machine for Human Riding Based on Machine Vision," *Transactions of the Chinese Society for Agricultural Machinery*, 2016.

[6] B. Li, H. Zhu, L. Fang, Y. Zhu, and S. F-ang, "Design and experimentation of craw-ler tea harvesting machine," *Journal of the Chinese Institute of Engineers,* vol. 47, no. 5, pp. 482-491, 2024, doi: 10.1080/02533839.2024.2346485.

[7] Y. Zhu *et al.*, "Deviation Tolerance Performance Evaluation and Experiment of plucking End Effector for Famous Tea," *Agriculture*, vol. 11, no. 2, 2021, doi: 10.3390/agriculture11020128.

[8] Y. Yang, I. V. Chicherin, L. Zhao, and C. Long, "Design and Research on Servomechanism of Tea Plucking," *Vestnik of Kuzbass State Technical University*, no. 1, pp. 14-22, 2024, doi: 10.26730/1999-4125-2024-1-14-22.

[9] T. Wang, B. Chen, Z. Zhang, H. Li, and M. Zhang, "Applications of machine vision in agricultural robot navigation: A review," *Computers and Electronics in Agriculture,* vol. 198, 2022, doi: 10.1016/j.compag.2022.107085.

[10] X. Hua *et al.*, "A Review of Target Recognition Technology for Fruit plucking Robots: From Digital Image Processing to Deep Learning," *Applied Sciences,* vol. 13, no. 7, 2023, doi: 10.3390/app13074160.

[11] K. S. Kiangala and Z. Wang, "An Industry 4.0 approach to develop auto parameter configuration of a bottling process in a small to medium scale industry using PLC and SCADA," *Procedia Manufacturing*, vol. 35, pp. 725-730, 2019.

[12] R. Langmann and M. Stiller, "The PLC as a Smart Service in Industry 4.0 Production Systems," *Applied Sciences,* vol. 9, no. 18, 2019, doi: 10.3390/app9183815.

[13] J. Hajda, R. Jakuszewski, and S. Ogonowski, "Security Challenges in Industry 4.0 PLC Systems," *Applied Sciences,* vol. 11, no. 21, 2021, doi: 10.3390/app11219785.

[14] M. Lee, J. W. Kim, Y. Mo, and A. D. Walker, "A review of professional learning community (PLC) instruments," *Journal of Educational Administration,* vol. 60, no. 3, pp. 262-287, 2022, doi: 10.1108/jea-03-2021-0060.

[15] H. Salih, H. Abdelwahab, and A. Abdallah, "Automation design for a syrup production line using Siemens PLC S7-1200 and TIA Portal software," in *International Conference on Communication*, 2017.

[16] B. Hasan, S. U. H. Mohani, S. S. Hussain, S. Yasin, and O. Saeed, "Implementation of Supervisory Control and Data Acquisition - SCADA on a PLC and VFD Controlled Digital Mixing Plant Using TIA Portal," in *2019 4th International Conference on Emerging Trends in Engineering, Sciences and Technology (ICEEST)*, 2019.

[17] H. He, Y. Long, and W. Yu, "Design and Simulation of Elevator Emergency System Based on TIA Portal V15.1," *Journal of Physics: Conference Series,* vol. 1802, no. 4, p. 042089 (5pp), 2021.

[18] K. J. Alaameri, A. J. Ramadhan, A. Fatlawi, and Z. S. Idan, "Design of a new sorting colors system based on PLC, TIA portal, and factory I/O programs," *Open Engineering,* vol. 14, no. 1, 2024, doi: 10.1515/eng-2022-0547.

[19] G. Gabor and G. Livint, "Solution for Monitoring and Remote Control Based on Modbus RTU and S7-1200 PLC," presented at the 2021 International Conference on Electromechanical and Energy Systems (SIELMEN), 2021.

[20] S. Vadi, R. Bayindir, Y. Toplar, and I. Colak, "Induction motor control system with a Programmable Logic Controller (PLC) and Profibus communication for industrial plants - An experimental setup," *ISA Trans,* vol. 122, pp. 459-471, Mar 2022, doi: 10.1016/j.isatra.2021.04.019.

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The authors declare no conflict of interest.

About the author:
Yan Yang, T.F. Gorbachev Kuzbass State Technical University, (28, Vesennyaya street, Kemerovo, 650000, Russian Federation), School of Intelligent Manufacturing Engineering, Chongqing University of Arts and Sciences, (Chongqing, 402160, China)
Ivan Chicherin, T.F. Gorbachev Kuzbass State Technical University, (28, Vesennyaya street, Kemerovo, 650000, Russian Federation), e-mail: chiv.iap@kuzstu.ru
Lijun Zhao, School of Intelligent Manufacturing Engineering, Chongqing University of Arts and Sciences, (Chongqing, 402160, China)
Chanjuan Long, T.F. Gorbachev Kuzbass State Technical University, (28, Vesennyaya street, Kemerovo, 650000, Russian Federation), School of Intelligent Manufacturing Engineering, Chongqing University of Arts and Sciences, (Chongqing, 402160, China)

Contribution of the authors:
Yan Yang – research problem statement; scientific management; reviewing the relevant literature; conceptualisation of research; writing the text, data collection; data analysis; reviewing the relevant literature; drawing the conclusions; writing the text.
Ivan Chicherin – research problem statement; scientific management; reviewing the relevant literature; conceptualisation of research; writing the text, data collection; data analysis; reviewing the relevant literature; drawing the conclusions; writing the text.
Lijun Zhao – research problem statement; scientific management; reviewing the relevant literature; conceptualisation of research; writing the text, data collection; data analysis; reviewing the relevant literature; drawing the conclusions; writing the text.
Chanjuan Long – research problem statement; scientific management; reviewing the relevant literature; conceptualisation of research; writing the text, data collection; data analysis; reviewing the relevant literature; drawing the conclusions; writing the text.

Authors have read and approved the final manuscript.