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Retraction

Retracted: Application of Microcontroller-Based Multipath Servos in Industrial Robot Control Systems

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] R. Hu, "Application of Microcontroller-Based Multipath Servos in Industrial Robot Control Systems," *Journal of Robotics*, vol. 2023, Article ID 7235120, 11 pages, 2023.

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Research Article

Application of Microcontroller-Based Multipath Servos in Industrial Robot Control Systems

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In recent years, nanotechnology has continued to develop, especially the use of nanomaterials in various fields. Microcontroller is the most typical embedded system at this stage. With the development of science and technology, microcontroller has been widely used in people's production life. A simple and practical multiservo controller can be built by using microcontroller and LED control chip PCA9685, which can realize at least 16 channels of servo control. In this paper, the control program of multichannel actuator is designed in detail, and the speed regulation of multichannel actuator is studied, which is applied to the industrial robot system driven by actuator. Nanomaterials, as new materials with various unique properties, have great application prospects, and this paper investigates the extension of nanomaterials in the field of robotic systems.

1. Introduction

1.1. Servo. Servos are control systems with constantly changing angles and are often used as position servo drives capable of holding angles. They have many advantages and are often used in a wide variety of civil electromechanical systems.

In microcontroller-based systems, the simplest way to control rudder motion is to generate PWM waves and vary the duty cycle using the microcontroller's internal timing source. Using a single microcontroller to generate multiple rudder control signals is a cost-effective and versatile method currently used to accurately, reliably, and consistently control multiple rudders in a reasonable and compact design. A typical rudder motion control is achieved by generating 20 ms PWM pulses and varying the duty cycle [1].

Simple rudder control can be achieved using the PWM control principle by simply connecting the control line of the rudder to one of the control pins of the microcontroller. However, articulated and multilegged robots need to control multiple servos simultaneously, i.e., multiple PWM signals must be controlled by a single multiplexed servo controller.

The internal structure of the servo is shown in Figure 1, including DC motor, reducer, potentiometer comparator, and control circuit. The DC motor is driven at high speed and through the reducer at low speed and high torque.

1.2. Microcontroller Overview. Microcontrollers are very small and complex microcomputers with data processing capabilities, integrated using very large-scale integrated circuit technology to enable high speed processing of data and information [2]. Microcontrollers are mainly used to interconnect components through a bus, each with different characteristics and playing different roles.

Microcontrollers are used in industrial automation because of the large number of I/O lines, very rich instructions, and very powerful logic operation performance.

1.3. Current Status of Robot System Development. Industrial robots are important automation equipment for modern manufacturing and have a very wide range of applications in many fields. Regarding the history of industrial robots, the first industrial robot was developed in the United States in 1962. Robotics is an important part of the high-tech field. The development of industrial robots in China is promising and dynamic, but there are still many difficulties and shortcomings to fully meet the needs of

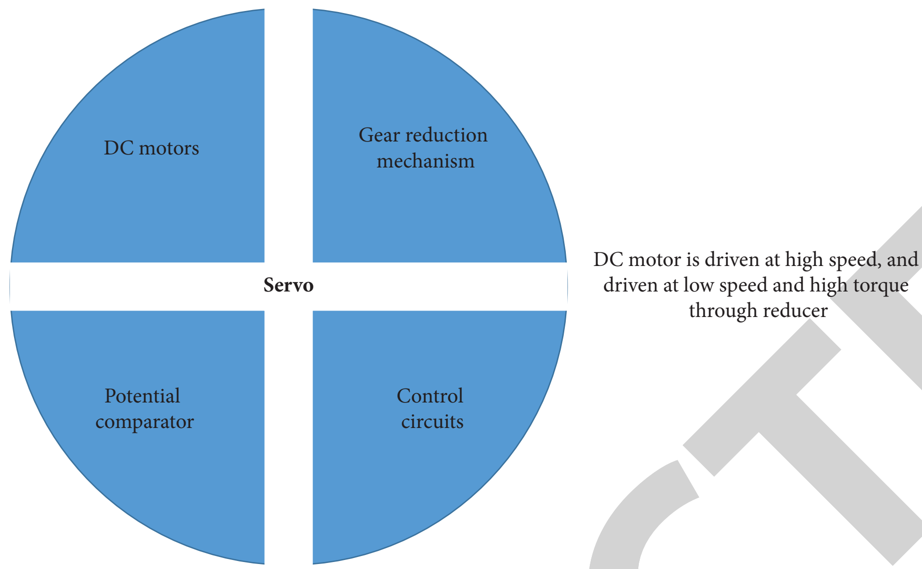

Figure 1: The internal structure of the servo.

industrial production and life. The traditional industrial robots often appear in front of people with the image of cold steel, and this image has been solidified, but this is only the traditional industrial robots, and the flexible robots currently under development are different from this, changing people's view of robots in terms of adaptability, safety, and interactivity [3]. Figure 2 shows a general industrial robot system.

1.4. Development of Nanotechnology. Nanotechnology is an integrated field of science and technology that studies the properties and interactions of materials at the nanoscale (generally considered to be less than 100 nm) and the exploitation of these properties. Nanobiosensor is a fusion of nanotechnology and biosensor, and its research includes several important disciplines, including biotechnology, information technology, nanoscience, and interface science. It also combines the application of various advanced detection technologies such as light, sound, electricity, and color. In recent years, nanobiosensors have attracted more attention than ever before due to the active development of nanoscience and interface science. Their development is remarkable and applications are widespread [4].

Nanomaterials are materials with nanoscale structures and molecular sizes of 1–100 nm, which are invisible at the macroscopic level. Nanomaterials themselves possess many unique properties such as small size, surface, and quantum effects. For example, inorganic antimicrobial agents can be incorporated into materials by nanodispersion and modification techniques to create nanobacterial materials and the small size effect of nanomaterials can be used to create infrared photodetectors and infrared cloaking technologies [5].

Another active area of research in the biomedical field is "nanorobotics." The development of nanorobots is related to the field of molecular bionics and involves the development of prototypes for the design and fabrication of "functional molecular devices" that operates in the nanoscale space based on biological principles at the molecular level.

2. Technology Principle

2.1. Servo Control Principle. The composition of the rudder is relatively simple. The power provided by the DC motor is attenuated by a reduction gear, and the torque is transmitted outward through the output axis. The rudder control process is shown in Figure 3. The servo contains a reference circuit that generates a reference signal with a period of 20 ms and a width of 1.5 ms. The actuator control signal is a pulse width modulated PWM signal of 0.5 to 2.5 ms, which corresponds to a steering angle of 0° to 180°[6]. If the control pulse signal does not change, the actuator can remain at a certain angle without moving. The three wires of the servo are connected to a multiservo controller, which can drive multiple servos in coordinated motion by multiservo control.

Here is an example of the PCA9685 chip, which is a controller chip designed to control LED backlighting [7]. The brightness of the PCA9685 chip can be changed according to the need and modified program output. Its main features are as follows

(1) The chip has a wide operating voltage range within which it can be adjusted arbitrarily, and each output can be configured for an open-drain operation at 25 mA or a pull-pull operation at 10 mA.

(2) The output frequency can be synchronized between several different devices by adjusting the internal 25 MHz oscillator. The output frequency range of the chip is 40~1000 Hz.

(3) The chip uses the I^2C bus to read or write new programs to the chip. The PCA9685 chip has four programmable I^2C bus addresses, which can be addressed simultaneously in these four bus addresses, which greatly improve the efficiency of

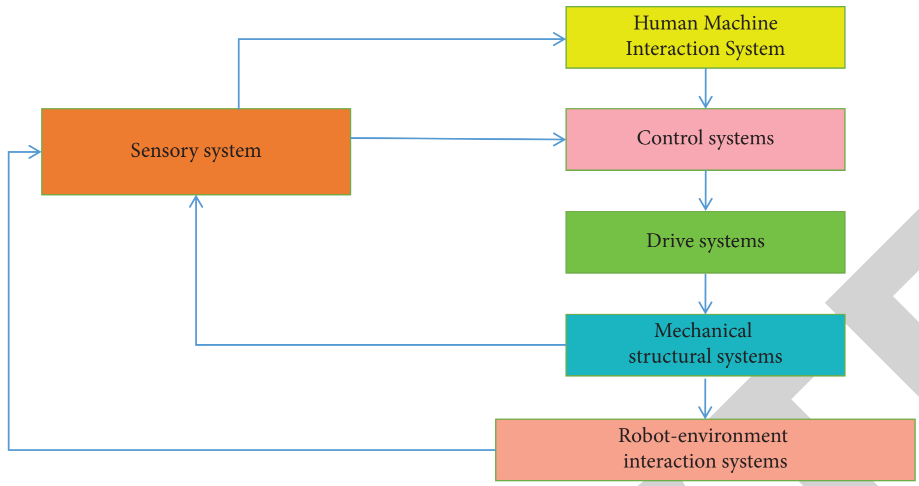

Figure 2: Industrial robot system composition.

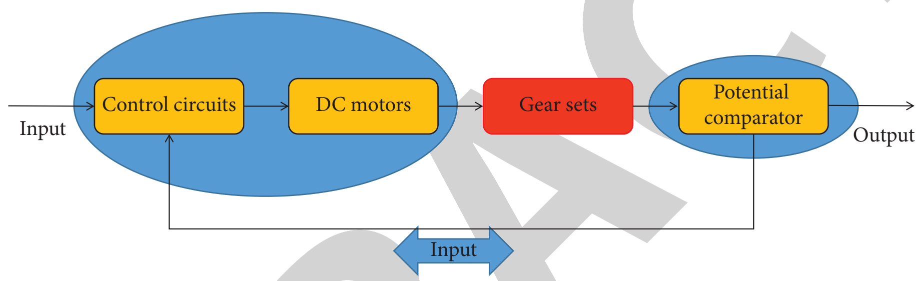

Figure 3: Servo control principle.

reading and writing. Up to six pieces of hardware can be connected to the I^2C. The PCA9685 chip is generally connected through these six pins.

(4) The chip can independently output a high number of pulses, which makes the implementation of multiplexed servos provide the necessary conditions.

(5) The chip form factor in the TSSOP28 package commonly used for the PCA9685 chip is shown in Figure 4.

Some pin definitions about the chip are shown in Table 1.

2.2. Nanobots. The emergence of nanorobots has provided new ideas for the innovation and development of modern biomedicine, with the ability to enter the human body in a minimally invasive manner, which is not possible with any conventional medical technology. However, despite the advances made in medical nanorobotics over the past decade, the immature technical requirements of the field such as the actuation and cluster control of microrobots limit the widespread use of these tools in clinical settings, and the simultaneous actuation of a certain number of nanorobots often requires cumbersome procedures and advanced instrumentation.

Fabrication, actuation, and degradation are fundamental to the application of nanorobots. At the nanoscale, the motion of a microrobot is influenced by both low Reynolds number and Brownian motion, and its motion must take

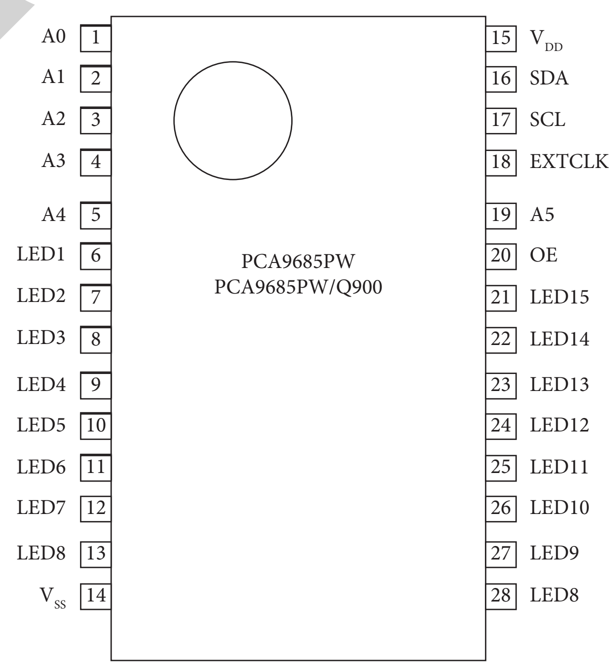

Figure 4: Chip form factor of PCA9685 chip.

into account environmental effects; so designing a nanorobot is primarily about enabling it to produce continuous motion and requiring it to have sufficient power to overcome the resistance of its environment. For example, microrobots

Table 1: Partial pin definition of PCA9685 chip.

Symbols	Pins TSSOP28	Pins HVQFN28	Type	Description
A0	1	26	I	Enter address 0
...	...	...	...	...
A4	5	28	I	Enter address 4
LED0	6	3	O	LED driver 0
...	...	...	...	...
LED15	22	19	O	LED driver 15
V_{SS}	14	11	Power supply	Supply land
OE	23	20	I	Active low output enable
A5	24	21	I	Enter address 5
EXTCLK	25	22	I	External clock input
SCL	26	23	I	Serial clock line
SDA	27	24	I/O	Serial data line
V_{DD}	28	25	Power supply	Supply voltage

can be made from catalytic materials and propelled into directional motion by using a catalytic reaction in H_2O_2 to create bubbles; microrobots with a spiral structure can be given magnetism, and a magnetic field can be used to cause the spiral to rotate itself, which in turn propels it into linear motion; for nanorobots with an asymmetric structure, ultrasound can be applied to create a pressure gradient to propel them into motion. Different types of micro-nanorobots have different manufacturing methods and drive methods, and the nontoxic degradation of the nanorobots is important for the safety of living organisms.

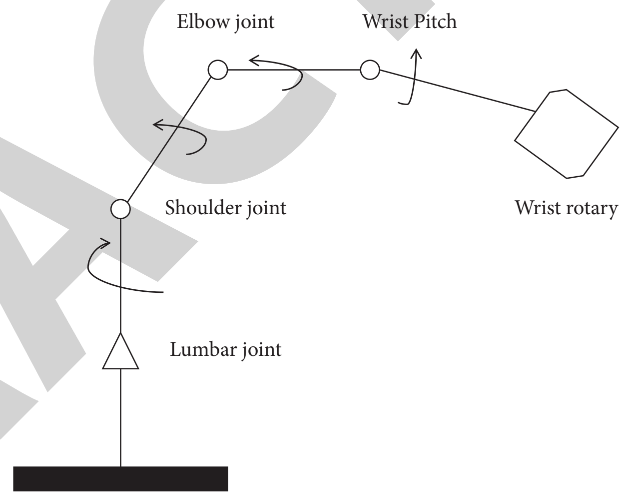

Figure 5: General-purpose robot structure.

2.3. Industrial Robot Control System. Industrial robots, which represent modern technology, are used in many production sites. Industrial robots also have a certain degree of danger, and the slightest carelessness can cause irreparable damage, which means that the control system of industrial robots is very demanding. The study of robot control systems is to prevent all kinds of losses and injuries, and of course, advanced control systems are also a manifestation of strong technical power [8].

Today, robots are mainly used for repetitive labor in industrial production. Generally, repetitive simple labor that is more injurious or polluting has been replaced by robots for manual labor, and a structure of five joints is generally considered sufficient. The schematic structure of this type of robot body is shown in Figure 5.

As can be seen in the figure, the composition of a universal robot is not complex, and the movement of multiple joints is all that is needed to fully control the actions of that robot. For example, the wrist joint determines the posture of the wrist. Therefore, centralized or hybrid control, as in the past, is difficult, and in the latest research, distributed control systems are promising and less technically difficult to implement. In this paper, the system control scheme, the hardware architecture, and the software architecture are described separately.

2.3.1. Overview of the Robot Control System. Distributed control system (DCS-Distributed ControlSystem) is an advanced control technology that was rapidly developed in the 1970s. Due to the various disadvantages of traditional control systems and the advantages of distributed control systems, most modern robot control systems now use distributed control structures. The development of distributed control systems has evolved with times, which means that the structure of industrial robots is diversified [9].

While the general-purpose industrial robot in the above example is a three-joint structure, an industrial robot using the now common distributed control system is a five-joint multijoint structure. This structure uses a distributed control system consisting of a central unit and five contactors. It consists of an upper and lower structure with an upper unit and a lower unit. The upper unit (master) uses an industrial PC to manage the entire system, perform human-machine interaction, coordinate conversion, and route interpolation calculations, coordination between slaves, and fault detection. The role of the lower unit (slave) is to provide feedback to the signals from the host machine, specifically in the form of control of the five joints, by which the motion of the robot is changed. The entire control system is shown in Figure 6.

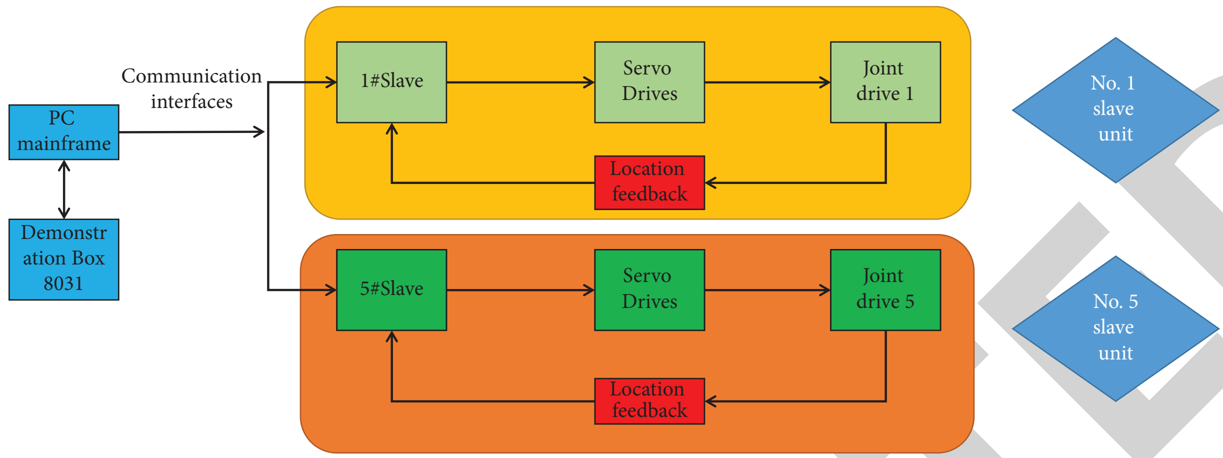

Figure 6: Distributed control system.

Based on the above five-joint robot theory, the control system has been developed for many years, and various component modules have become quite popular and cheap, so the development difficulty is low. In the control system, not only the weak electrical system but also the strong electrical system is needed to cooperate with it. Here, the five-joint motor unit is part of the strong electrical system, and the strong electrical control line is also essential. In terms of structure, the combination of strong and weak control systems makes the structure quite compact, especially when changing the design of the robot body. Thus, the control system is highly flexible and versatile [10].

During operation, the control system controls peripheral devices, coordinates their movement with the robot, and receives signals from sensors inside the robot. The peripheral devices are managed by the host computer, and information interaction between the major units within the control system does not go through the host computer, but uses serial communication interaction. Full-duplex asynchronous serial ports are used to communicate between the main control unit and them. All I/Os of the controller and sensors inside the robot of peripheral devices are isolated by optical coupling [11].

2.3.2. Joint Servo. Unlike the more complex unit model of the control system, in the basic structure, the joints have a motor composition, which is simpler. The principle of the motor is shown in Figure 7. The position signals from the coding channels A and B of the coding board are converted into signals that can be recognized by the next unit after a series of processing and feedback on the action of the motor. 8031 compares the position with the position given by the host in a 2-byte operation to form a position deviation. This control quantity is converted into an analog signal by a 12-bit D/A converter, converted to level, amplified, and then sent to the joint servo unit as control power to close the joint motor position. To make the counter work more accurately, the method generally used is to synchronize the counter latch with the timing of the 8031 via clock pulses. The slave must also smooth the given position and smooth the moving joints according to the robot's needs [12].

2.3.3. Master-Slave Communication Method. There are various ways of information interaction between master and slave machines, but their fundamentals are all one principle. After a long time of development, the communication technology between the master and slave machines has become very mature. Technically speaking, it is a single-chip communication method using serial communication in this system to solve the information exchange between multiple CPUs. Common single-chip communication methods are parallel port and serial communication. Based on the characteristics of the transmission signal, serial communication is generally used because of its simple structure and can be used for long-distance communication [13]. Although parallel communication has the advantage of fast communication speed, it is not practical and is very unsuitable for master-slave communication applications. Asynchronous serial communication is used in industrial robot controllers because many microcontroller chips have built-infull-duplex asynchronous serial ports that can send and receive data simultaneously. This allows the use of serial communication directly between a master processor and several slave 8031 communication processors.

2.4. Nanomaterial Preparation Methods. Nanomaterials are formed in three dimensions by transforming ordinary materials into microparticles using multidisciplinary knowledge of chemistry, physics, and biology. The following five methods are commonly used to prepare nanomaterials [14]:

(1) *Hydrothermal Method.* Nanomaterials need to be prepared under high temperatures and pressure. Under high temperature and pressure conditions, raw materials are hydrolyzed into nanomaterials through chemical reactions. Many nanomaterials are reactive, and high temperatures and pressure provide

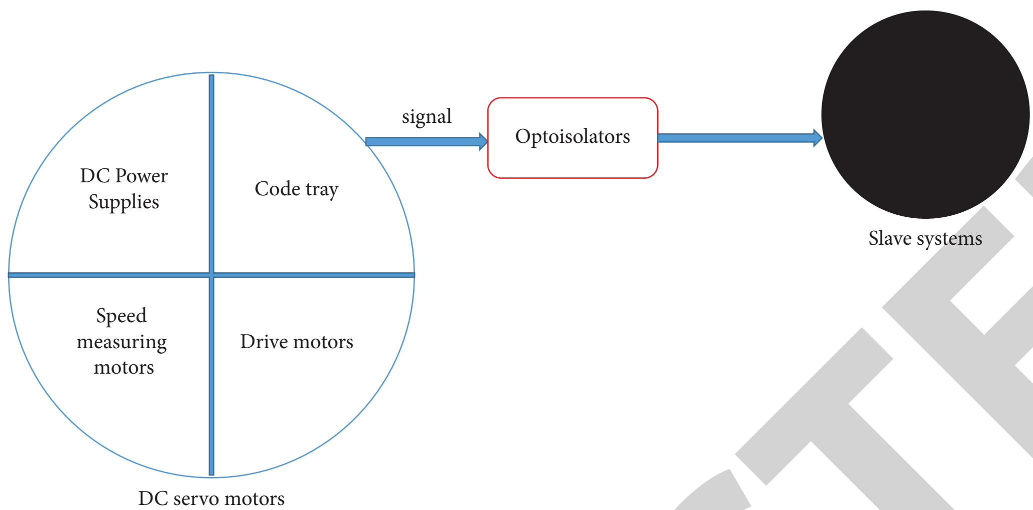

Figure 7: Motor principle.

suitable conditions for the preparation of nanomaterials.

(2) *Precipitation Method*. The precipitation method is a form of nanomaterial preparation that uses chemical conclusions. Generally, precipitation involves chemical changes, and solution reactions are extremely good chemical reactions that are usually carried out in solution when using this method of preparation. After ensuring that the reaction is complete, it needs to be precipitated and dried to obtain the desired nanomaterial. Nanomaterials prepared by the precipitation method usually have high purity.

(3) *Gas-Phase Reaction Method*. The gas-phase reaction method is also very efficient in preparing nanomaterials by reacting with gaseous metal compounds using a chemical reaction. Because the contact area of the gaseous material is maximized, this method is energy efficient and environmentally friendly compared to other methods.

(4) *Evaporation Coalescence Method*. The evaporation coalescence method is also a common method for preparing nanomaterials, which involves the decomposition of nanoparticles by heating and evaporation, separation into single molecular and atomic structures under high-temperature conditions, and rearrangement of the decomposed atoms and molecules by scientific means and formulas. Unlike the hydrothermal method, this method does not require a high-pressure environment. The advantage of nanomaterials produced by the evaporation-drying and solidification method lies in their small diameter, which far exceeds the requirements of general nanomaterials and their wide range of applications.

(5) *Spray Method*. Unlike the chemical reaction of the precipitation method, this method does not involve a material change in the raw material and is based on physical changes that do not require complex experiments and only require atomization of the solution by various physical means. Nanomaterials prepared in this way can generally reach submicron standards and produce uniformly dispersed fine particles. Table 2 summarizes the characteristics of the five methods.

2.5. Overview of Microcontroller Principles and Application Design. No matter what the system is, it is used by people, so it is necessary to go to the community first to research the needs of the system and other aspects. Therefore, the design of a microcontroller application system is also inseparable from the first step of research to clarify the feasibility characteristics of the software and hardware. As part of the feasibility study, it is necessary to collect information about the research on the system from all over the world to study and use the successful and advanced experiences, advantages, and disadvantages. Disadvantages need to be analyzed, and if there is no similar experience, detailed study and research on the design and development environment of the microcomputer system are needed. The final design is still up to the people themselves, but in the design process, the stability of the structure must be considered, the cost also needs to be accounted for, and a combination of all aspects also needs to be tried to improve the compatibility of the system, so that the designed system is excellent. Ensure the efficiency of the software and hardware designs [15].

2.5.1. Software Design of the Microcontroller. In the design process of the microcontroller software system, it is required that after the circuit design is finalized, the hardware design and software design must be considered comprehensively to clarify the software design issues and ensure that the design meets the functional requirements of the system.

The generality of the microcontroller software is very important. The purpose of the design process should be clear and modified according to the actual situation in the field.

Table 2: Five preparation methods of nanomaterials.

Preparation method	Main process	Features
Evaporation coalescence method	Decomposition of raw materials and rearrangement of the atoms and molecules	Small diameter of nanomaterials
Sedimentation method	Solution state mixed precipitation, prepared after drying	Higher purity of nanomaterials
Spray method	Atomizing raw material solution to break up nanomaterials	Uniform material distribution and fine grain
Hydrothermal method	Hydrolysis of raw materials under high temperature and pressure	Guaranteed balance
Gas-phase reaction method	Synthesis of ultrafine particles through chemical experiments	Low energy consumption, low cost, and high efficiency

The design tasks should be changed under the following different requirements:

(1) After understanding the needs of the microcontroller, the first thing to consider is how to use the software rationally. It is necessary to understand the functions of the software, the need for a deep analysis of the software architecture. When necessary, the software can be decomposed so that the software design is seen from an independent perspective.

(2) In order to improve the efficiency of the software design, it is necessary to create a proper flow chart of the program. After this step, it is very clear to observe the improvement of efficiency, which is very beneficial for the software design of the microcontroller.

(3) The mathematical software design model accurately describes the mathematical relationships between various input and output variables in order to provide improved software design performance based on the general system requirements of the software. In microcontroller application system software, RAM is a very important component. 8031's on-chip RAM has fewer cells but an extremely large number of reserved bytes, so it is a great challenge to apply the cells and bytes resources in a reasonable way, so the allocation must give full play to their respective advantages. Second, when the 8 cells of RAM are working registers, R0 and R1 have certain pointer functions, some of which are very large and cannot be applied elsewhere. Third, the 16 bytes of 2OH–2FH also have a straightforward function and can be used to store various flag bits, store logic variables, store status variables, and so on by means of bit addressing. Once the RAM resource allocation design is completed, it should be easy to read and use in the programming session. A detailed resource allocation table should be created. The resource allocation design for this RAM is shown in Figure 8.

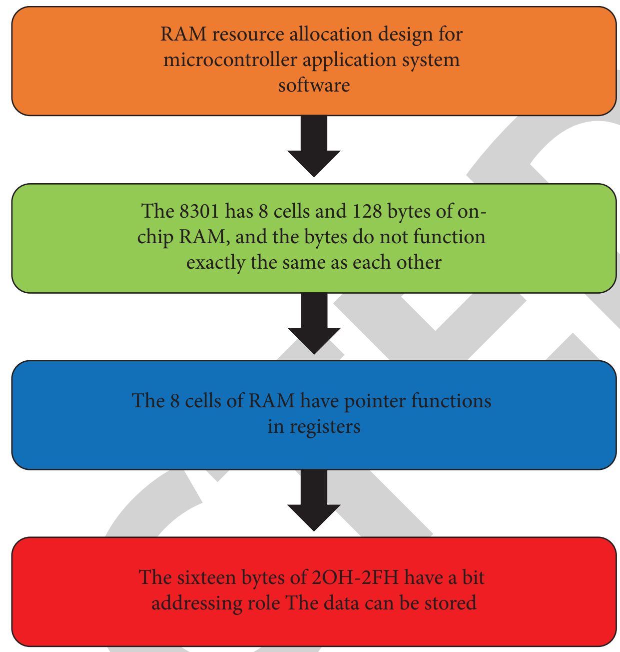

Figure 8: Design of RAM resource allocation.

2.5.2. Hardware Design of the Microcontroller. The hardware design of the microcontroller-based system mainly includes the design of system extensions and functional modules. Since microcontrollers are very application-oriented and require different hardware modules for different requirements, a detailed consideration of requirements in terms of hardware expansion is needed. After considering the requirements, it is also necessary to focus on the human-computer interaction aspect. For example, after the microcontroller has finished running the required program, it is necessary to display the results in front of the subject, for which the hardware module is necessary. The design of the system hardware should focus on the development of a general layout plan and a detailed and thorough technical justification. At the same time, the key circuit components should be studied in detail and in depth, tested, and analyzed before the design begins, and the results obtained should be verified as satisfactory by designing several indicators. If the requirements of the design are not met, i.e., if it does not pass the test, then such a design is substandard and must be improved upon to ensure that the entire analog circuit design is verified.

3. Application of Multipath Servo in Industrial Robot Control System

3.1. PCA9685-Based Design. By reviewing the manual, we can understand the characteristics of the PCA9685 chip [16]. There are many reasons for choosing this chip in this paper, including its low power consumption, fast response, and more pins and thus more functions, but the main thing is the output capability of the PCA9685 chip. We can learn that the chip can independently output multiple PWM waves and can be adjusted. By adjusting the 16 PWM pulses from the chip to match the PWM pulses required for steering control and changing the duty cycle as needed, multiple steering control can be achieved. The system uses the widely used STC microcontroller as the main controller and the PCA9685 chip as the PWM signal generator to establish multiplexed servo control.

3.1.1. Hardware Circuit Design. The PCA9685 chip has a relatively good design with many pins and comes with more functions, so many functions can still be implemented without adding peripheral devices. Here, the six address pins of the chip are used to determine the address at high and low levels. This system uses a PCA9685 with all address pins connected low as the chip address [17].

In the manual, you can learn that the PCA9685 uses the I^2C bus communication method.

3.1.2. Software Design. The PCA9685 is designed to output PWM waveforms through several basic steps, which are the same in most devices that output PWM, but the exact details vary. The following is an overview of the basic steps to output a PWM waveform [18]:

(1) Determination of Chip Access Address. The chip access format of the PCA9685 is shown in Figure 9. The upper bits are fixed to 1, the lower bits are read/write mode selection, and bits 2 through 7 are determined by the external level of the chip. In this system, all six pins of the hardware address are connected to a low level, so the chip read/write commands are determined. In the PCA9685 chip, the role of each register is determined by setting different parameters; after that, it is very convenient to implement the required function because we only need to write control words to the set registers. The operating mode and communication registers of the chip are not the same under different addresses. The PWM output is also changed by controlling the registers.

(2) Control Mode Selection. The PCA9685 has two operating modes, and for reasons of ease of use, operating mode 1 is used, and the corresponding register address can be queried to be 00h. The chip is designed to be used in the following ways. The specific C program code is as follows: write8 (PCA9685_MODE1, 0×0), where write8 ( ) is the I^2C write function; PCA9685_MODE1 is the mode 1 register address [19].

(3) PWM Wavelength Setting. It is very important to control the action period of the servo; too fast or too slow will lead to different degrees of consequences. After the study, it was decided that the PWM period required for the control of the servo is set to 20 ms [20]. At the same time, the frequency of the PWM wave is set to 50 Hz, and the value of the frequency setting is calculated by the following formula:

$$\text{prescale\_value} = \text{round}\left(\frac{\text{osc}_{\text{clock}}}{4096 * \text{upda te}_{\text{rate}}}\right) - 1. \quad (1)$$

Formula (1) outputs frequency calculation.

The set value is calculated to be 121 when a PWM frequency of 50 Hz is required to be the output. The chip's operating frequency can be changed by loading a value into the frequency setting register. Please note that the frequency can only be changed when the PCA9685 chip is in the sleep mode. Set the frequency by formula (2).

$$\text{unsigned char pulse} = 121. \quad (2)$$

Formula (2) calculates the frequency setting.

(4) Pulse Width Adjustment. From the control principle of the servo, to make the servo rotate, it is necessary to change its control parameters, as mentioned above that the rotation of the servo is achieved by adjusting the pulse width of the PWM wave output by the microcontroller. Each output port of the PCA9685 has a 12-bit counter that can count from 0 to 4095 with a count interval of 1/4096 PWM cycles. The output ports rely on two on/off control registers, LED_ON and LED_OFF. By writing the count values to the corresponding registers, the on/off times of the ports and the corresponding pulse widths can be obtained, thus controlling the output waveform [21]. The servo can generally rotate half a week, which corresponds to a PWM waveform with a positive pulse width of 0.5 to 2.5 ms, and then the relationship between the servo rotation angle θ and the pulse width ω is calculated by the following formula:

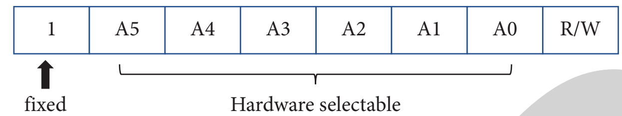

Figure 9: PCA9685 chip access format.

$$\omega = 0.5 + \frac{2}{180}\theta. \quad (3)$$

Formula (3) calculates the rotation angle and pulse width relationship.

The PCA9685 operates at 20 ms cycles with each count interval of 20/4096, and the corresponding count value is calculated by the following formula:

$$\text{Count} = \text{Round}\left(\frac{4096}{20}\omega\right) - 1. \quad (4)$$

Formula (4) is used for counting interval calculation.

Regarding the correspondence between the pulse width of the servo and the axis position in the software, it is listed in Table 3.

The response time of each stage of the servo movement according to the points in Table 3 was tested under both no load and nominal load, and the results are shown in Table 4.

3.2. Servo Smooth Drive. Let a certain way servo travel S be set from (initial axis position P0) 45° to (desired axis position P1) 90°. This amount of travel is subdivided into intermediate positions, each of which has a drive signal [22]. Subdividing the travel S into N intermediate positions, the response time required from the 45° position to the first position and each subsequent position is: T_{m0}, T_{m1}, T_{m2}, ...T_{mN}, setting the response time relationship as in formulas (5) and (6).

$$T_{m_0} = T_{m1} = T_{m2} = \ldots = T_{mN}. \quad (5)$$

Formula (5) calculates response time relationship.

$$T_{m0} + T_{m1} + T_{m2} + \ldots + T_{mN} = T_{sum}. \quad (6)$$

Formula (6) is used for actual movement time calculation.

T_{sum} is the actual time of motion, while the mean angular velocity ω is calculated with the following formula:

$$\overline{\omega} = \frac{S}{T_{m0} + T_{m1} + T_{m2} + \ldots + T_{mN}} = \frac{S}{T_{sum}}. \quad (7)$$

Formula (7) is used to calculate average angular velocity.

Table 3: Correspondence between pulse width and axis position.

Pulse width (ms)	0.5	1	1.5	2	2.5
Axis position	0°	45°	90°	135°	180°

Table 4: Response for no load and nominal load.

Response time (ms)	Phase (°)			
	0~45	45~90	90~135	135~180
No-load response	140	140	140	140
Nominal response	140	140	140	140

For this example of 45° stroke, set $N \geq 6$, $T_{m0} = T_{m1} = T_{m2} = \ldots = T_{mN} = 20$ ms; the advantages of this method are as follows: (1) the average angular velocity is lower; stability can be guaranteed; (2) motion controllability increases the motion process of controllable features position more; motion smoothness is improved.

3.3. Nanobot Drives. Nanorobots can move both individually and in clusters. Their actuation methods largely influence their speed, ease of control, and biocompatibility, which in turn affects their application in biological systems. The main driving methods for nanorobots are chemically driven by local chemical and biochemical energy, physically driven by external fields (e.g., light, ultrasound, or magnetic fields), and biologically driven by microorganisms or cells.

External field drive is mainly used here. Most externally field-driven nanorobots do not require fuel and are, therefore, biocompatible and sustainable, mainly using light, ultrasonic, or magnetic field drives. They are more flexible in terms of controlled movement than chemically-driven nanorobots. Magnetic field-driven nanorobots can also be driven without any added fuel or harm to the human body. Magnetic field drive is based on the use of magnetic materials to build nanorobots that respond to external magnetic fields. The external magnetic fields are classified as rotating, gradient, oscillating, etc. For example, remote controllability and precise motion of three-dimensional magnetic tubular robots can be achieved by external magnetic fields, and these tubular robots have good capabilities in the capture, targeted delivery, and release of silica particles.

4. Conclusion

This paper focuses on the application of multiplexed servos in industrial robot systems, introducing the principles of nanomaterials, multiplexed servos, and industrial robot control systems. Based on the PCA9685 chip, a multiplexed servo control system can be established with a single machine as the core controller to realize the group control function of more than 16 servos. The principle of the servo and the software and hardware for designing the servo are highlighted to achieve smooth and stable drive control. The multi-way servo has a coherent and smooth motion with reduced jitter characteristics. Because its control is not affected by the timing fluctuations of the microcontroller, it has quite good accuracy and antiinterference performance, and experiments show that it is quite versatile.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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References

[1] W. Wang, X. Yu, B. Fang et al., "Cross-modality LGE-CMR segmentation using image-to-image translation based data augmentation," *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 1, 2022.

[2] W. Shao, Z. You, L. Liang et al., "A multi-modal gait analysis-based detection system of the risk of depression," *IEEE Journal of Biomedical and Health Informatics (JBHI)*, vol. 26, no. 10, pp. 4859–4868, 2022.

[3] H. Rao, S. Wang, X. Hu et al., "A self-supervised gait encoding approach with locality-awareness for 3D skeleton based person Re-identification," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 44, no. 10, pp. 6649–6666, 2022.

[4] T. Wang, K. Fang, W. Wei, J. Tian, Y. Pan, and J. Li, "Microcontroller unit chip temperature fingerprint informed machine learning for IIoT intrusion detection," *IEEE Transactions on Industrial Informatics*, vol. 19, no. 2, pp. 2219–2227, 2023.

[5] T. Wang, B. Lu, W. Wang, W. Wei, X. Yuan, and J. Li, "Reinforcement learning-based optimization for mobile edge computing scheduling game," *IEEE Transactions on Emerging Topics in Computational Intelligence*, vol. 7, no. 1, pp. 55–64, 2023.

[6] E. Emad, O. Alaa, M. Hossam, M. Ashraf, and M. A. Shamseldin, "Design and implementation of a low-costmicrocontroller-based an industrial delta robot," *WSEAS Transactions on Computers*, vol. 20, pp. 289–300, 2021.

[7] Z. Zhong, Y. Ding, S. Wu, and Y. Guo, "Design of RS422 bus-basedmulti-servo network controller[J]," *Journal of Kunming Metallurgical High School*, vol. 37, no. 3, pp. 71–77, 2021.

[8] X. Chen, C. Zhang, and L. Zhu, "Design of a six-degree-of-freedom robotic arm control system based on micro-controller," *Journal of Tongling College*, vol. 20, no. 2, pp. 106–109, 2021.

[9] W. Li, Y. Liu, S. Ge, and D. Liao, "Research of mechanical resonance analysis and suppression control method of the servo drive system," *Shock and Vibration*, vol. 2021, Article ID 5627734, 15 pages, 2021.

[10] R. Rodríguez-Ponce and F. G. Mota-Muñoz, "Microcontroller-based direct torque control servodrive,"

Journal of Robotics, vol. 2020, Article ID 9152494, 11 pages, 2020.

[11] L. Y. Hsiao, L. Jing, K. Li, H. Yang, Y. Li, and P. Y. Chen, "Carbon nanotube-integrated conductive hydrogels as multifunctional robotic skin," *Carbon*, vol. 161, pp. 161784–161793, 2020.

[12] Y. A. Lv, "Design of industrial automation robot control system based on fuzzy PID system," in *Proceedings of the 2019 3rd Scientific Conference on Mechatronics Engineering and Computer Science (SCMC2019)*, pp. 236–239, Dalian, China, March 2019.

[13] S. L. Zhang, S. Wang, F. Jing, and M. Tan, "A sensorless hand guiding scheme based on model identification and control for industrial robot," *IEEE Transactions on Industrial Informatics*, vol. 15, no. 9, pp. 5204–5213, 2019.

[14] B. Mustafa Can and A. Y. Omur, "Performing predefined tasks using the human-robot interaction on speech recognition for an industrial robot. Engineering Applications of Artificial Intelligence," *The International Journal of Intelligent Real-Time Automation*, vol. 13, Article ID 95103903, 2020.

[15] C. Huang and W. Zhang, "Navigation control method of indoor mobile robot based on visual servo," *International Journal of Antennas and Propagation*, vol. 2022, Article ID 6422841, 10 pages, 2022.

[16] B. Li, W. Tian, C. Zhang, F. Hua, G. Cui, and Y. Li, "Positioning error compensation of an industrial robot using neural networks and experimental study," *Chinese Journal of Aeronautics*, vol. 35, no. 2, pp. 346–360, 2022.

[17] H. Gao, S. Lu, T. Wang, Shouyin, and T. A. O. Wang, "Motion path planning of 6-DOF industrial robot based on fuzzy control algorithm," *Journal of Intelligent and Fuzzy Systems*, vol. 38, no. 4-1, pp. 3773–3782, 2020.

[18] A. Giakoumis, C. Volos, A. J. M. Khalaf et al., "Analysis, synchronization and microcontroller implementation of a new quasiperiodically forced chaotic oscillator with megastability," *Iranian Journal of Science and Technology Transactions of Electrical Engineering*, vol. 44, no. 1, pp. 31–45, 2020.

[19] J. C. Ehiabhili, V. Ezeh Chioma, and V. Orji Onyeka, "Single phase microcontroller-based automatic change over switch," *Journal of Electronics, Communication and Instrumentation Engineering Research*, vol. 9, no. 1, pp. 35–43, 2019.

[20] X. Guan, S. Lou, H. Li, and T. Tang, "Intelligent control of quad-rotor aircrafts with a STM32 microcontroller using deep neural networks," *Industrial Robot: The International Journal of Robotics Research and Application*, vol. 48, no. 5, pp. 700–709, 2021.

[21] D. Chariag and L. Sbita, "Implementation of different randomized PWM schemes using Atmega328p microcontroller for EMI reduction in boost converter," *Electrical Engineering*, vol. 102, no. 2, pp. 1063–1071, 2020.

[22] "Towards a safe development of reconfigurable robotic systems," *WSEAS Transactions on Systems and Control*, vol. 14, pp. 14359–14374, 2019.