Design of Autonomous Navigation Picking Robot Based on MCU and GPS Positioning

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***Abstract* — This paper studies the design of autonomous navigation picking robot based on MCU and GPS positioning. Researching on the key technologies of the picking robot can not only meet the demand of the market and reduce labor intensity, but also keep up with the pace of the new developing agricultural technology in the modern world and improve economic efficiency. The experiment result shows that the efficient and performance can be improved after using autonomous navigation picking robot based on MCU and GPS positioning.**

Keywords - design; autonomous navigation; picking robot; mcu and gps positioning

I. INTRODUCTION

The picking robot is an integrated system, which can implement environmental awareness, dynamic decision-making and planning, and movement control. Research on the key technologies of the picking robot can not only meet the demand of the market and reduce labor intensity, but also keep up with the pace of the new developing agricultural technology in the modern world and improve economic efficiency.

At the same time, it is important to improve Chinese agricultural modernization. Chui [1] made some research on a prototype of the picking robot, such as modeling of the picking robot, control method, real-time obstacle avoidance algorithm and the design of control system software and hardware. Kinematics simulation modeling of the picking robot is done in his research. Through analyzing the robot's mechanical structure, he had finished building the camera model and the mobile platform model. In the meantime, we have adopted the geometric structure algorithm to establish forward and inverse kinematics equations of the picking robot. Thus he had laid basic theoretical foundation for the robot control

Wei [2] conducted research on control methods of the picking robot based on the characteristics of the robot's mechanical structure. Meanwhile, Wei designed an image-based visual serving controller and adopted controlling algorithms of small step approximation to guide the robot's end-effector to orientate the target exactly and designed a fuzzy-PID controller according to the nonlinear and strong coupling characteristics of the servo control system and put it in use to the servo motion control of the robot's manipulator joints.

Pereira designed picking robot's control system. In terms of openness and real-time principle, we finished building the open software and hardware platform for the picking robot's control systems. In the hardware design, he focused mostly on the selection for the following key modules that compose the control system, such as industrial personal computer, serial communication interface converter, joint drive motor. He selected sensor in conformity with its working characteristics and designed corresponding signal acquisition circuit, thereby equipping it with such abilities as image acquisition, target localization, perception of the obstacles, position limiting protection and so on. As a result, the robot gets better in intelligence and perception of the environmental information on the external. As for the software design, mainly from the perspective of real-time, Zhang [4] applied the technology of VFW to achieve real-time image acquisition and worked out a real-time obstacle avoidance search algorithm. On the basis of VC ++ language, we utilized multi-threading technology to accomplish the whole control system software, which is capable of serial communications, image capture, target recognition, real-time obstacle avoidance control and limit protection.

Zhang carried on experiments with the picking robot platform in both laboratory and orchard environment in [5]. In the laboratory environment, the picking robot can finish the work automatically and continuously with a relatively high rate of successfully picking. Whereas, it could only preliminary complete picking operations in the complex orchard environment and showed general effect with a certain gap from the expected outcomes. These results demonstrate that the picking robot's control system developed in our subject has relatively good reliability and a certain degree of adaptability. However, the picking robot's control system is necessary to be further optimized if we want to achieve the goal of continuous harvesting operations in orchard environment.

II. THE FRAMEWORK AND BASIC MODEL FOR PICKING ROBOT

Fruit and vegetable picking job is part of the whole fruit and vegetable production process, which is time and energy consuming. Its degree of automation is far behind of other sectors of agricultural production. With the rising cost of human resources and the popularity of both the large-scale and automation of agriculture, it is necessary study fruit and vegetable picking robot. This paper completes hardware and software design of robot control system against the existing six degrees of freedom picking robot mechanism and conducted relevant experiments of robot.

Ref. [5] studied significance of picking robot and the present researching and study status in the world, and then introduced the robot's structure and operating manner, carries out the hardware design of robot control system, which mainly indicates the selection of motor and drive and the motion control card, circuit design and Construction of control system hardware. Secondly, it finishes control parameters configuration and PID tuning of PMAC. Then it introduces the theory of binocular vision system and completes camera calibration in use of the calibration method. It also studies the target identification which is through the image dealing method of linearization and median filtering and the eight regional connectivity area segmentation approaching and target localization which combines with calibration result. It completes the software design of the control system including the control program of both PMAC and stepper motor motion control card. It also develops the robot binocular vision system program of camera calibration, target identification, position calculation etc. and completes robot upper software program. Based on the above, picking robot motion control and visual servo systems eventually satisfies the design requirements to complete the binocular positioning experiment and manipulator motion control experiment of picking robot, which contribute to the development of next generation of picking robot and the application of robot with actual practicing value. The basic framework is shown in the following figure 1.

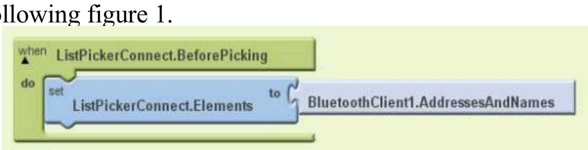

Figure 1. The basic framework

Internet, mobile communication and satellite-based navigation are three most important industries in the information society of 21st century. Meanwhile, the technical level and the development course of GPS system represent the development status of the satellite navigational system in the whole world. At present, our country has already become a great user of GPS. The satellite navigation industry chain has basically been formed. Nevertheless, we have not gone deep into the core GPS technology, as the most important part of our GPS products are mostly import.

Complex signal processing has to be done to synchronize the local signal with the received one when a GPS receiver works. How to acquire the satellite signal and keep track of it is one of the most important techniques in the GPS receiver technology. Many researchers have come up with lots of solutions on that question, but most of them are only on the theory level, and are difficult to apply them in a GPS receiver system to do the real-time processing. It has researched and designed a GPS signal acquisition and tracking system on FPGA based on the analysis of the algorithms existing. In that course, a GPS receiver module has firstly been designed and made using Nemerix Corporation's GPS chip group. It works stably and can be used as a GPS baseband signal processing research platform that outputs real-time GPS IF signal. Based on that, the article researches deeply on the GPS signal acquisition and tracking technique.

It compared several GPS signal acquisition solutions, and determines to use the step forward correlation in [7]. Then analyzes the characteristics of tracking loop, and determines to make FLL and PLL work in turn to track the carrier and let the carrier assist the pseudo-code tracking. All of these solutions have finally been realized. The GPS signal acquisition and tracking system in this theme is realized by the operation of the hardware cooperating with the software. The hardware mainly realizes the functions of correlate that have high data rate and simple logic, and the software based on Micro Blaze processor mainly realizes the functions that have low data rate and complex logic. Liu [8] gave detailed design and simulation results of the hardware circuit and detailed flow of the software design. The figure 2 shows the principle of operation for GPS.

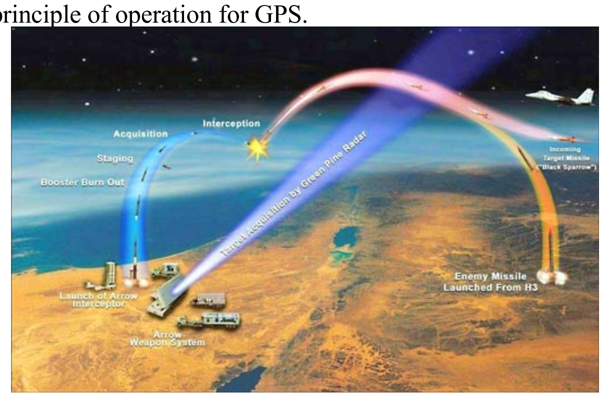

Figure 2. The principle of operation for GPS

III. THE DETAILED DESIGN

We describe and express the spatial relationship of the two rod pieces of the manipulator, which simplifies the kinematics question to solve the 4×4 equivalent transformation matrix that connects the ends coordinates system and the fixed reference coordinate system, i.e., the kinematical equation of the robot. Figure 3 shows the structure diagram of the picking robot. Figure 4 is the schematic diagram of the connecting rod coordinate system

Figure 3. The structure diagram of the picking robot

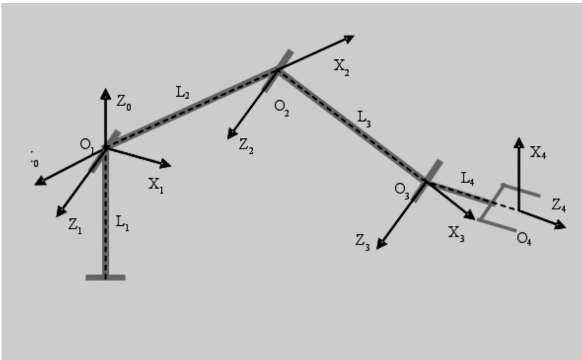

Figure 4. The connecting rod coordinate system

When the spatial relationship between the two adjacent connecting rods i-1 and i changes in accordance with the following motions, the coordinate transformation can be accomplished.

1) Revolve θi around axes Zi-1 until it reaches the position where axes Zi-1 is parallel to axes Zi;

2) Translate distance di along axes Zi-1 to cause Xi-1 to be collinear with Xi

3) Translate distance λi along Xi to cause the coordinate system origins of the connecting rods to be coincided;

4) Revolve angle λi along Xi to cause axes Zi-1 to be collinear with axes Zi

The basic algorithm is shown as the equation (1):

$$C^1 = C - C^0,\ e^1 = e - e^0,$$
$$\eta^1 = \eta - \eta^0,\ \rho_1 = \rho - \rho_0 \tag{1}$$

$$f(x,\omega) = f^0(x,\omega) + \int_V \mathcal{S}(x-x')(\mathrm{L}^1 F(\mathrm{y}') + \rho_1\omega^2 \mathbf{g}(R)\mathrm{T}_1 f(\mathrm{y}')]S(\mathrm{y}')\mathrm{dy}' \tag{2}$$

Then we get:

$$\frac{1}{\Gamma(1+\alpha)}\int_R \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha = \lim_{\varepsilon\to 0}[\frac{1}{\Gamma(1+\alpha)}\int_{-\infty}^{x-\varepsilon} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha + \frac{1}{\Gamma(1+\alpha)}\int_{x+\varepsilon}^{\infty} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha] \tag{3}$$

$$g_{ik}(\bar{k},\omega) = -\frac{1}{\eta_{11}^0}\frac{1}{\bar{k}^2} + \frac{1}{\rho_0\omega^2}\left(\frac{e_{15}^0}{\eta_{11}^0}\right)^2 \frac{\beta_\perp^2}{\bar{k}^2-\beta_\perp^2},$$
$$\gamma_i(\bar{k}_i,\omega) = \frac{1}{\rho_0\omega^2}\left(\frac{e_{15}^0}{\eta_{11}^0}\right)^2 \frac{\beta_\perp^2}{\bar{k}^2-\beta_\perp^2} m_i \tag{4}$$

Where,

$$\alpha^2 = \frac{\rho_0\omega^2}{C_{11}^0},$$
$$\alpha^2 = \frac{\rho_0\omega^2}{C_{66}^0},\ \beta_\perp^2 = \frac{\rho_0\omega^2}{C'_{44}},$$
$$C'_{44} = C_{44}^0 + \frac{(e_{15}^0)^2}{\eta_{11}^0} \tag{5}$$

Rewrite again Eq. (4) as

$$\hat{f}_H^\alpha(x) = \frac{1}{\Gamma(1+\alpha)}\int_{-\infty}^{\infty} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha = \frac{1}{\Gamma(1+\alpha)}\int_{-\infty}^{\infty} f(t)g(x-t)(dt)^\alpha = f(x)*g(x), \tag{6}$$

$$\partial_j(C_{ijkl}\partial_k u_l + e_{kij}\partial_k\varphi) - \rho\ddot{u}_i = 0 \tag{7}$$

$$\partial_j(e_{ijkl}\partial_k u_l - \eta_{kij}\partial_k\varphi) = 0 \tag{8}$$

The linear equation can be expressed in the following simplified forms:

$$L(\nabla,\omega)f(x,\omega) = 0$$
$$L(\nabla,\omega) = T(\nabla) + \omega^2\rho\mathrm{J} \tag{9}$$

Where,

$$T(\nabla) = \begin{Vmatrix} T_{ik}(\nabla) & t_i(\nabla) \\ t_k^T(\nabla) & -\tau(\nabla) \end{Vmatrix},\ \mathrm{J} = \begin{Vmatrix} \delta_{ik} & 0 \\ 0 & 0 \end{Vmatrix},$$

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$$f(x,\omega)=\begin{Vmatrix} u_k(x,\omega) \\ \varphi(x,\omega) \end{Vmatrix} \tag{10}$$

The TMS320F2812 chip from TI Company was selected to be the control chip. This chip is a 32-bit fixed-point DSP chip which is suitable for use in industrial control, motor control etc. Its running clock can reach 150MHz, and each instruction cycle is 6.67ns. It has 128k x16-bit on-chip FLASH, 18kx16-bit SRAM and abundant peripheral interfaces. In order to reduce the difficulty of the system design, the mature development board QQ2812 was selected. This development board equipped with the F2812 chip and commonly used peripherals and interfaces. Fig. 5 shows the system function block diagram. The communication between the image processing unit and the DSP controller was achieved by RS232 serial port, transmitting the three-dimensional coordinate information of each plucking. According to the position gotten from image processing unit, the DSP can achieve the close-loop control of DC servo motor on X,Y and Z axis and the open-loop control of gripper steer engine.

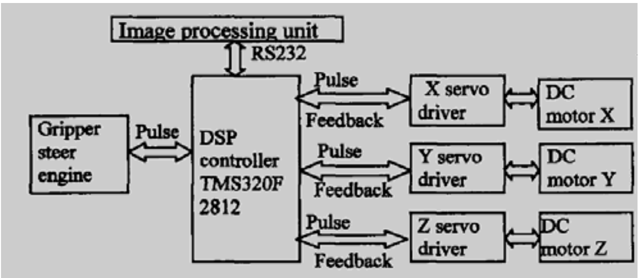

Figure 5. The system function block diagram

This system has 3 DC servo motor whose model is MAX32. Due to the system's mobile power and take energy issues into consideration, a small probability 20 W DC motor and dear reducer drive program was selected. After the DSP receive the txt data file from image processing unit, the data was specially processed and convert into the position information of the respective axes. Then DSP sent a certain number of pulses to control the motor to rotate a certain angle, so that the each axis can move to the specified location. The motor control system was composed of three control loops which are current loop, velocity loop and position loop. Under the work condition each motor moves according to DSP's construction, and through the three closed loop DSP can achieve high precision velocity control and the position control.

The software was designed by CCS3.3 (Code Composer Studio), using C language and assembly language to achieve all the function. System is initialized after powered on, then steps into the communicating stage, receiving position data from the image processing unit, after which X, Y and Z axis move and the gripper close, picking the tea. Simultaneously, the blower work and the tea are drawn back into the collection box, completing a picking action. Then the system will detect whether all the position have been completed. It will go to next area, if completed. Otherwise, it will go to the next position. After having been developed and debugged, the software was flashed into the FLASH memory of the DSP from the TTAG port via USB emulator. Then it was copied to RAM when working to improve the running speed. After powered on, the system orderly calls concerning functions which contain initializing function, position initializing function-pos init(), communicating function-data_readQ, coordinate detecting fuction-pos_dectQ, 5 action functions and 3 DSP counter overflow interrupt functions.

IV RESULTS AND DISCUSSION

The mechanical body is the execution unit of the picking robot whose performance index has immediate impact on the quality of the operation task. The mechanical performance index of the robot, which reflects the tasks competent for the robot and the operability it possesses, is determined by the factors such as accuracy of mechanical manufacture, the joint clearance of the transmission bending deflection, kinematics error of the joint servo motor, and the control system performance.

The performance index can be evaluated from various aspects like kinematics, dynamics and control methods. Among which, kinematics performance has the biggest influence on the operation performance of the vegetable-fruit picking robot.

Test of the forward kinematics solution. The forward kinematics solution for the 4 DOF picking robot is theoretically solved according to D-H transformation of the robot joint coordinate system. Experiments are done to test and verify the correctness of the forward kinematics solution and the robot performance. Six groups of the joint variables are chosen randomly from the robot joint space. The robot starts motion from zero point. The actual positions of the manipulator in the robot base coordinate frame are measured. The six groups of the joint variables are substituted into the forward kinematics solution equation to obtain the theoretical position. The test result of the forward kinematics solution can be obtained with actual position compared with the theoretical position.

Matlab is a high-level language with high efficiency used in scientific engineering calculation. It is also good at visual display of data in that it is capable of showing data's two, three or even four dimensional manifestations. Fig. 6 and Fig.7 show respectively the picking robot's working space drawn with Matlab's three dimensional plotting function plot3 and its projection on Plane xoz.

The result of calculation shows that the robot's working space V equals 1.92m3, and the volume index reaches 0.64. The simulation results prove such designed robot meets the expectations for eggplant picking in greenhouse and is able to work more efficiently. The simulation validates the rationality of the structure design

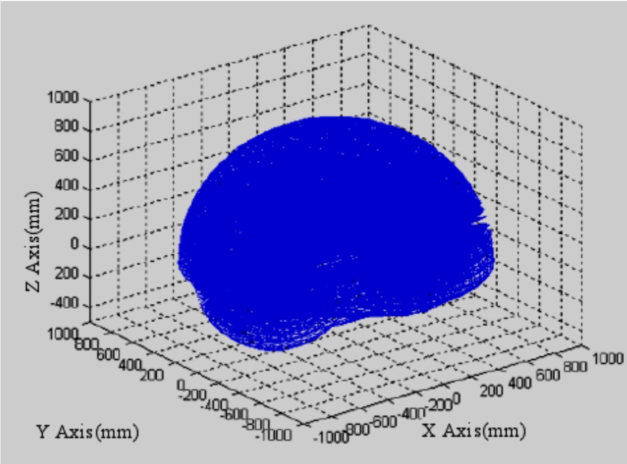

Figure 6. The working space for picking robot

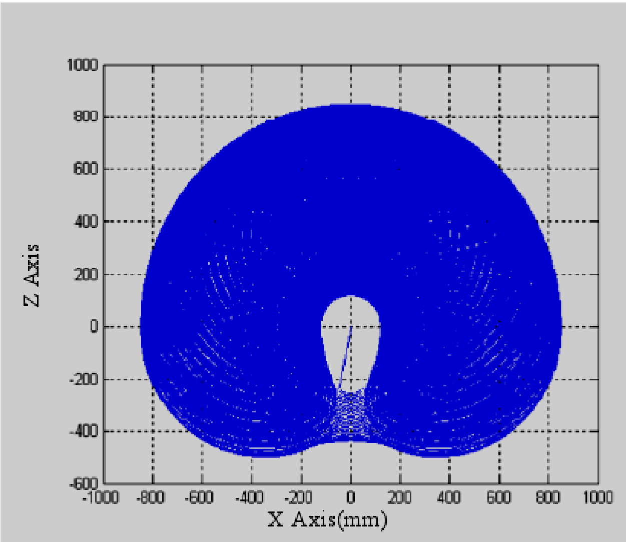

Figure 7. The Projection of the working space on Plane xoZ

V. CONCLUSION

This paper studies the design method of autonomous navigation picking robot based on MCU and GPS positioning. Researching on the key technology of the picking robot can not only meet the demand of the market and reduce labor intensity, but also keep up with the pace of the new developing agricultural technology in the modern world and improve economic efficiency. It selected sensor in conformity with its working characteristics and designed corresponding signal acquisition circuit, thereby equipping it with such abilities as image acquisition, target localization, perception of the obstacles, position limiting protection and so on. As a result, the robot gets better in intelligence and perception of the environmental information on the external. The experiment result shows that the efficient and performance can be improved after using autonomous navigation picking robot based on MCU and GPS positioning.

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