ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0035

Design of Target Control System based on STM32

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Abstract

Aiming at the functional design defects of the current shooting training system, which is not conducive to improving the shooting level of individual soldiers, a target control system based on STM32 is designed to help individual soldiers improve their shooting level. The system uses C# technology for upper computer software development and ZigBee technology for interaction between upper and lower computers. The upper computer software undertakes the main functions, including target manual control mode and target automatic control mode, show grades and other functions. The lower computer is responsible for lifting and falling target operation and data acquisition. The system can realize multi-mode control of the target and improve the comprehensive shooting ability of individual soldiers.

Keywords

The Shooting Training System, Zigbee Technology, Multi-Mode Control, STM32.

1. Introduction

Shooting is a necessary skill for individual soldiers and is also one of the key skills to evaluate the quality of individual soldiers. In the battlefield environment, the accuracy of shooting and the speed of reaction means the existence or not of life, and to a certain extent, it means victory or defeat in wars or campaigns [1]. Therefore, individual shooting is a subject that all services and arms, cadres and soldiers, recruits and veterans must undergo training and assessment every year. The traditional target control system has a single training mode, mostly fixed upright or mobile rail targets. This training mode makes individual soldiers easy to form fixed thinking, which is not conducive to improving the comprehensive shooting ability of individual soldiers [2]. With the development of the economy and science and technology in China, the requirements for networking and automation of target control systems are becoming higher [3,4]. In order to improve the training efficiency of individual soldiers and cultivate their comprehensive ability, the system develops the software and hardware of the target control system based on STM32 [5,6]. The system improves individual soldiers' comprehensive shooting ability through multi-mode control of the target. It adopts wireless communication technology and can carry out long-distance multi-target control, which greatly enhances individual soldiers' training efficiency. The software part of the system can display and record the results of individual soldiers shooting in real-time and query and manage the shooting results.

2. Design the Overall System Architecture

The target control system consists of three parts: the host computer software module, XBee wireless communication module, target motor control, and data acquisition module. The logical architecture of the system is shown in Figure 1 below.

The control centre in Figure 1 runs the upper computer software and serves as the control unit of the whole shooting training system. The database is used to store data. The sub-display module displays the number of hits and total scores in real-time for individual soldiers, and XBee wireless

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communication is used as the interactive medium between the upper computer software and the lower computer data. During shooting training, the upper computer software sends instructions to the lower computer to lift or fall the target, and the lower computer does corresponding actions according to the instructions. When the lower computer detects that the target is hit by a bullet or the target state changes, the lower computer sends the detected result or the target state to the upper computer. The gunnery training system is easier to deploy in the field because each sub has an XBee wireless communication module. The control centre communicates with the sub-display module through Ethernet, and the XBee wireless module is connected with the control centre PC or the lower computer through the serial port.

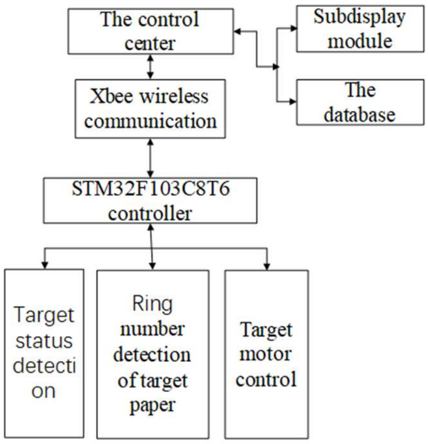

Figure 1. System logical architecture

3. Hardware Design of the System

The main choice of the target control system is the STM32F103C8T6 chip as the main controller, and the system hardware mainly includes XBee wireless communication module, motor control module and data acquisition module [7].

3.1 Motor Selection and Control Design

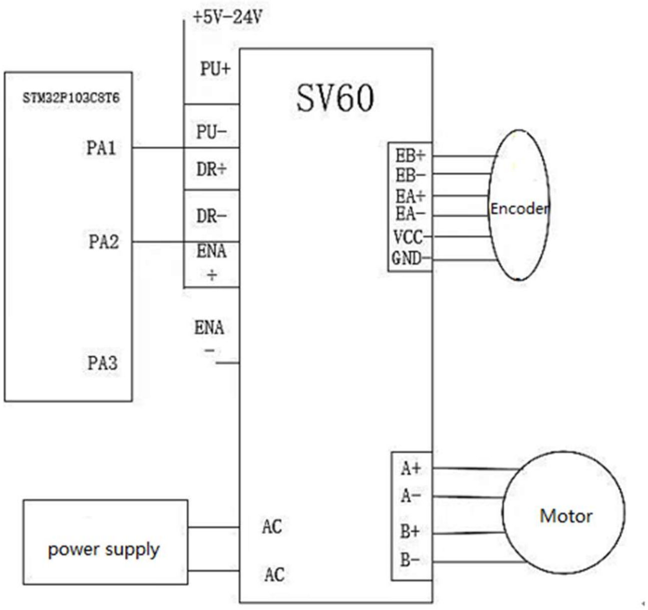

Figure 2. Motor drive control wiring diagram

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The target driving unit of this system selects the stepper motor of the 60SV-88-1000 model, and the driver selects SV60 closed-loop driver, which adopts DSP chip and vector closed-loop control technology to prevent lost steps [8]. After testing, the driver with 5 V ~ 24 V voltage can meet the target's fast up or down action.

The motor drive is connected to the port of the driver through the pin of STM32F103C8T6 [9]. When the PA1 pin of STM32F103C8T6 is a high voltage, the port of the SV60 closed-loop driver inputs PWM pulses to control the motor to rotate in the forward direction, and the target is lifted [10,11]. On the contrary, the PA2 pin of STM32F103C8T6 outputs low level, and the port of SV60 closed-loop driver inputs PWM pulse to control the reverse rotation of the motor, and the target falls. The wiring diagram is shown in Figure 2 below.

3.2 Design of Wireless Communication Module

As remote control is required, wireless modules are used for communication between the upper computer and the lower computer. Xbee-pro 900HP module based on ZigBee protocol is used in this system, as shown in Figure 3 below [12].

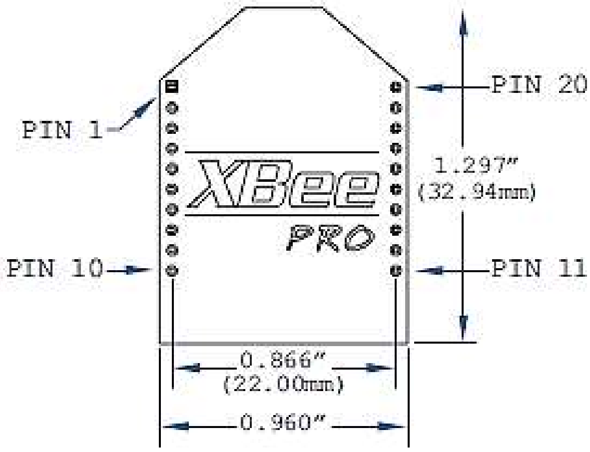

Figure 3. The XBee PRO 900HP module

Xbee-pro 900HP module has two working modes: transparent transmission and API [13]. Working in API mode, the packet format of communication between the upper computer software and the lower computer is fixed data frame format, as shown in Figure 4 below. According to the corresponding information contained in each data frame, the corresponding operation events are stimulated, and then the host computer software can control multiple field targets. The XBee-PRO900HP module is connected to the upper computer PC and the lower computer STM32F103C8T6 microcontroller through a serial port to realize the communication between the upper computer and the lower computer.

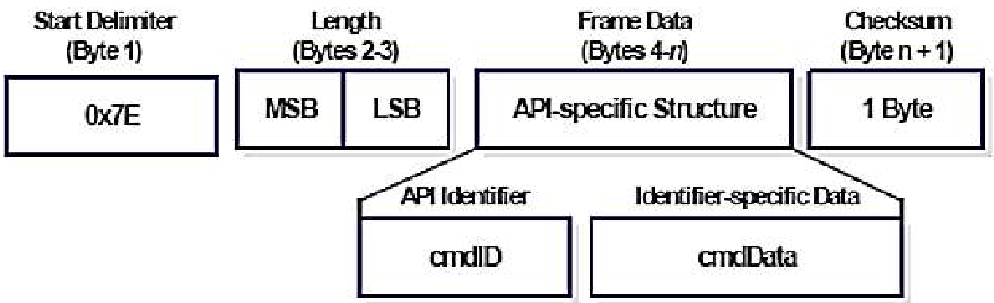

Figure 4. Data frame format

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3.3 Data Acquisition Module

In this system, the STM32F103C8T6 chip serves as the controller of the data acquisition module. Its main functions include parsing the received data frames, collecting the number of target paper loops, detecting the target state and sending data frames. The upper computer software sends the control instructions to the lower computer through the serial port, and the microcontroller receives and analyzes the control instructions through the serial port and controls the target for corresponding operations.

The lower computer collects the target paper ring number to determine the ring number through the acoustic and electric positioning of bullet hole coordinates. The positioning principle is that acoustic and electric sensors are installed around the target paper, and electrical signals are formed to the STM32 microcontroller according to the sound wave excited by the bullet. STM32 microcontroller starts to keep time until all electrical signals are received and stopped. The number of rings is then determined by determining the location of bullet holes based on the speed at which sound waves travel through the air and its time for sensors at various locations to receive them.

The detection of the target state is that the STM32 microcontroller detects the target state in real-time and sends the data frame of the state to the bit computer when it finds that the state changes.

4. Target Control Strategy and System Software Design

The control of the system is divided into manual control mode and automatic control mode. The manual control mode is divided into total control and single/multiple target control. The automatic control mode includes automatic control target lift or fall, automatic sequently control target lift or fall.

4.1 Manual Control Mode

When it is necessary to lift all targets during training, there is the following formula:

$$a = \begin{cases} t \ (\mathrm{P}_{ud} = 1) \\ d \ (\mathrm{P}_{ud} = 0) \end{cases} \tag{1}$$

Where a is the decision value, when P_{ud} is equal to 1, t is the decision value of lifting all targets, when P_{ud} is equal to 0, d is the decision value of hiding all targets. The show or hide status of the target is determined according to the final output decision value a.

When only part of the target needs to be lifted or down correspondingly controlled during soldier training, the decision judgment is also made with formula a. When P_{ud} is equal to 1, t is the target lifting decision value of the selected target. When P_{ud} is equal to 0, d is the decision value of the hidden target of the selected target, and the target state is determined according to the output value of a.

4.2 Automatic Control Mode

When soldiers use the automatic control mode to train their reaction ability and shooting accuracy, they first need to select the target and set the number of bullets used by the bureau, let the number of targets selected in each group be $R_i\,(i = 1,2,\ldots,\mathrm{n})$, where i is the group number, the number of bullets used in this bureau is B_i, the number of bullets is set to calculate the number of missed bullets shot by the soldier to which each target belongs, in order to facilitate the calculation of the number of training times in this bureau, it is recorded as n_t.

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4.2.1 Automatic Lifting or Falling Target Control

When the soldier's training task is to lift and fall the target automatically, first obtain the parameter values of the target display time, the hidden target time, and the number of cycles marked as $T_{sw}(\mathrm{sw}=1,2......\mathrm{n})$, $T_{hd}(\mathrm{hd}=1,2......\mathrm{n})$, N_{cl} respectively, where the units of T_{sw} and T_{hd} are seconds. The subscripts in T_{sw} and T_{hd} indicate the group number. According to the following logic formula (2) to judge the start and end of training.

$$on-off=\begin{cases}1\ (true)\\0\,(false)\end{cases} \tag{2}$$

In the above formula (2), when $on-off$ is 1, it means the training starts, and when $on-off=0$, it means the training ends.

When $on-off=1$, $n_c=0$, $\mathrm{P}_{ud}=1$ in formula (1), t is the lifted target decision value of $R_i\neq 0$ targets, output a, all $R_i\neq 0$ targets are lifted, then, according to each group's set T_{sw} and T_{hd} values, each group will lift or fall the target in a circular manner. The control case of the first group ($sw=1$, $hd=1$) is analyzed below, after $R_{i=1}$ targets are lifted, after ($T_{sw=1}+0.01$) seconds, $R_{i=1}$ targets are hidden, after T_{hd} seconds, denote a cycle as n_c+1, then after N_{cl} cycles, that is $n_c=N_{cl}$, $on-off$ is set to 0, this group of automatic target lifting and falling training is over. Finally, according to the number of bullets hit by each target in the group, it is denoted as $B_l(\mathrm{l}=1,2,......,\mathrm{n})$, where l is the number of soldiers participating in training in the group, able to separately calculate the number of missed targets or unfired bullets of each individual soldier in the round, that is B_i-B_l. The training control process of other groups' automatic lifting and the falling target is as above.

4.2.2 Automatic Sequentially Lift and Fall Target Control

When soldiers are training in the automatic sequentially lift and fall target mode, first, determine how many targets the bullet hits according to the following formula (3), target hiding.

$$D_i=\begin{cases}h\ \ (\mathrm{L}=true)\\g_i\ (\mathrm{L}=false)\end{cases} \qquad (i=1,2,...,\mathrm{n}) \tag{3}$$

In the formula: i is the group number; h and g are how many bullets hit the target to hide the target. When $\mathrm{L}=true$, $D_i=h$, that is, among R_i targets, the target will fall, no matter which target is hit by bullets h times. When $\mathrm{L}=false$, $D_i=g_i$, that is, The number of bullets that caused each group of targets to fall is different. Then, obtain the parameter values of the target display time T_1, the time T_2 between the targets, the number of cycles N_{cl}, and the cycle interval time. Among them, the time T_2 between targets is determined according to the following formula (4).

$$T_2=\begin{cases}x\ \ (\mathrm{L}=true)\\x_j\ (\mathrm{L}=false)\end{cases} \qquad (\mathrm{j}=1,2,......,n) \tag{4}$$

In the formula: x is the value of the inter-target time T_2, and x_j represents the value of the inter-target time T_2 is a random number.

After obtaining the above parameters, determine the start or end of training according to the value of $on-off$ in formula (2). when $on-off=1$, In each group of $R_i\neq 0$, the first target in each group is lifted, and after T_2 seconds, the second target in each group starts to lift, and so on, until the last target in each group is hidden, is a cycle, denoted as n_c+1. If $N_{cl}>n_c$, then in each set of targets, restart in the

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reverse order of $n_c - 1$ training, follow the above methods to control the lifting and falling of the target. Suppose $N_d = n_c$ the shooting training of this round is over.

4.3 System Software Design

The software design part of the target control system is mainly for the upper computer control software design and the lower computer system software design. The development language of the host computer control software is C#, the development platform is .NET Framework and supports multi-threaded development. The design process of the upper computer control software is that the system first configures the communication port and then sends a self-checking command to the lower computer for the detection of globally available targets. Finally, the .NET Framework's own timer is used to cooperate with each other to send corresponding control instructions to the lower computer according to the control strategies in the above sections 3.2 and 3.3, and at the same time, a thread is opened to monitor the data fed back by the lower computer.

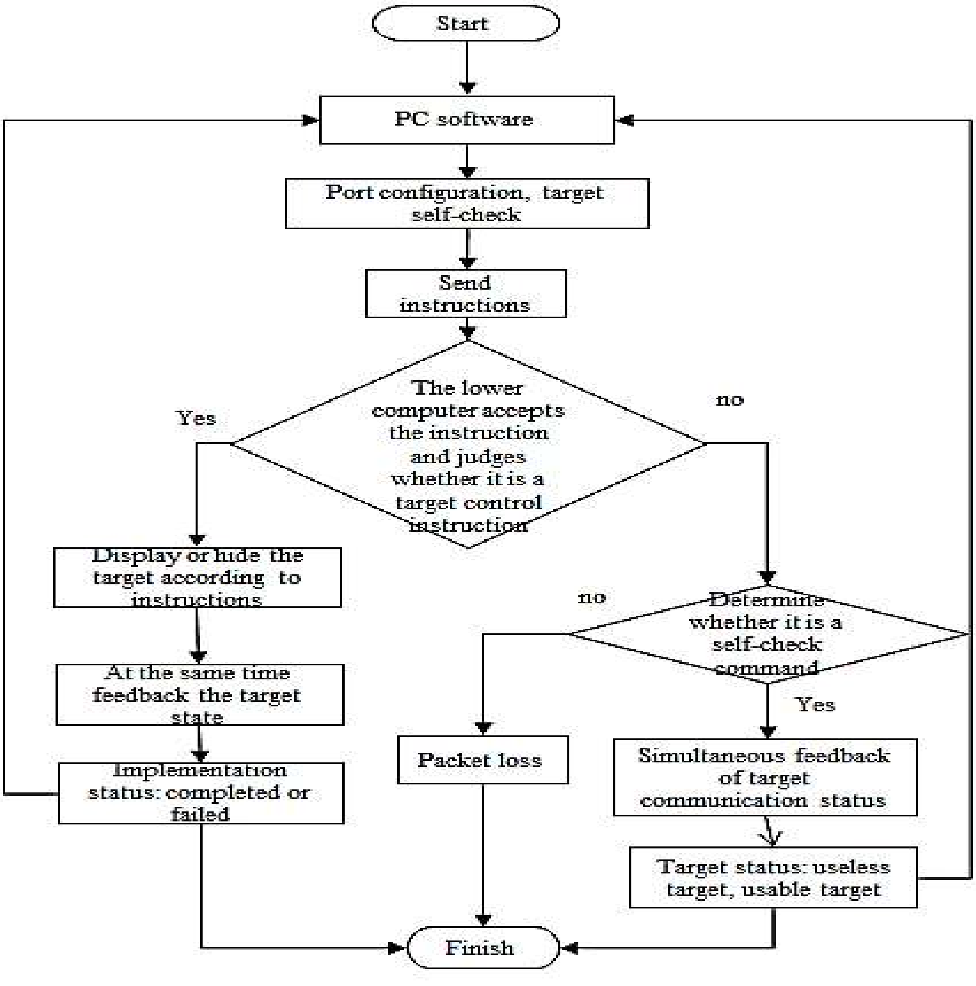

Figure 5. System software control design process

The system software design process of the lower computer is that after, the lower computer is powered on, it actively monitors the instructions sent by the upper computer software, parses the instructions and judges whether they belong to the system instructions. If the lower computer accepts the self-check command, it will feedback the running status to the upper computer. If the lower computer accepts a control instruction, In that case, it controls the target to lift or fall and actively feedback the target status after executing the instruction to the upper computer software.

The flow chart of system software control design is shown in Figure 5 above.

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5. Conclusion

This system uses the STM32F103C8T6 chip as the core processor, downloads the motor control program and data acquisition program to the STM32F103C8T6 MCU, and then combines with the host computer software to realize the target's Multi-mode lifting and falling control and data acquisition functions.

This paper introduces the upper computer's software part and the lower computer's hardware control part and studies the target control system based on STM32, which solves the problems of the single training mode and low efficiency of the traditional target control system. It is mainly reflected in the following two aspects: One is to increase the difficulty of training and improve the quality of training through Multi-mode lifting and falling control of the target. The second is the use of acoustic and electrical positioning bullet holes to realize the function of collecting and recording the ring number.

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