HIGH NOON SHERIFF ROBOT

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1. Introduction

Nowadays with the increasing number of armed attacks and shooting incidents. [1] The update for public places needs to be put on the agenda. Obviously, we could not let police and security to do all the jobs since humans might neglect some small action of threat behind hundreds of people and could not respond quickly to the threat. A second of hesitation might cost an innocent life. Our team aims on making some changes to this situation since nothing is higher than saving lifes not only victims but also gunners. We find some ideas in the Old western movies when two cowboys are going to a high noon duel, the sheriff will pull out the revolver quicker than the other and try to warn him before everything is too late. If we can develop a robot that can detect potential threats and pull-out weapons first to warn the criminal to abandon the crime or use non-lethal weapons to take him down if he continues to pull out his gun.

1.1 Functions

To achieve effective protection in a legal way, the robot should satisfy the following behavioral logic:

- When the dangerous person is acting normally and there is no indication of impending danger, the robot should remain in standby mode with its robot arm away from the gun.

- When the dangerous person is in a position ready to draw his gun or other indication of dangerous behavior, the robot is also in a drawn position and its arm is already clutching the gun.

- When the dangerous person touches his gun, The robot should immediately draw the gun, move the hammer and finish aiming and firing to control the dangerous person.

1.2 Benefits

Our project can enhance safety for consumers in several ways. Firstly, the robot equipped with sensors and weapons can react faster than human security personnel, potentially preventing an attack before it occurs. This can help reduce the number of violent incidents and increase overall safety. Secondly, deploying our robot in high-risk areas can reduce the risk of injury or death to human security personnel. With improved response times, our robot can quickly and accurately detect potential threats, leading to faster and more effective emergency responses. Lastly, using robots in public places may be more cost-effective than hiring and training additional human security personnel. Robots can work 24/7 without the need for breaks, making them a more efficient solution. Overall, robots have the potential to enhance safety, reduce risks, and increase cost-efficiency in security operations.

1.3 Features

Our robot design features three key elements. Firstly, it must have fast and reliable movement capabilities to draw and aim its gun faster than any potential opponent. Secondly, the robot should prioritize warning the opponent. If the opponent makes a move towards their gun, the robot should draw and aim its gun without firing. If the opponent surrenders, the robot should put its gun back in place. However, if the opponent persists in drawing their weapon, the robot will shoot. Thirdly, the robot must have accurate shooting capabilities. It should be able to shoot the opponent with precision, even if the opponent is moving. With these features, our robot design can provide fast, effective, and accurate security support.

1.4 High-level requirements list

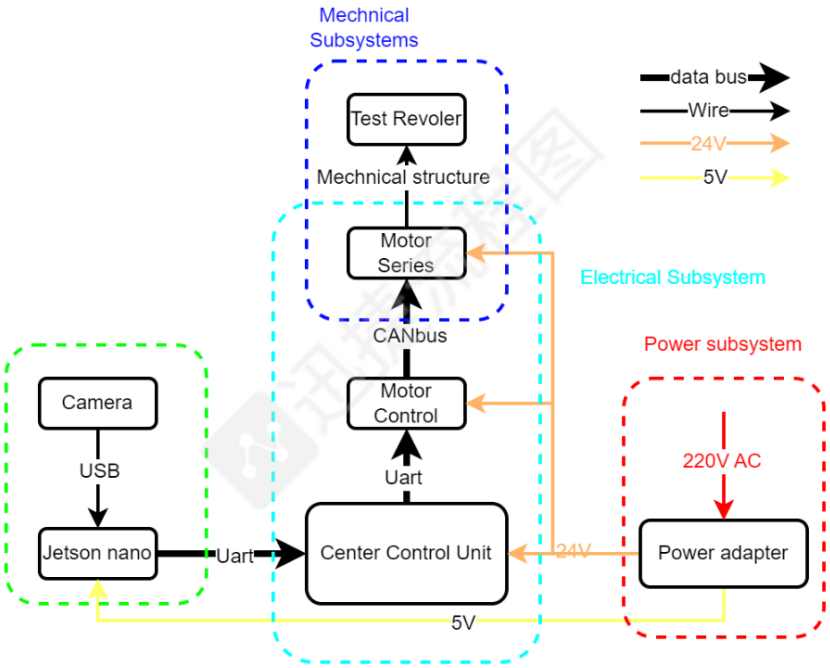
1. The robot must draw its gun and aim faster than the opponent, which means the entire process of detecting and making an action should be in a very low delay.

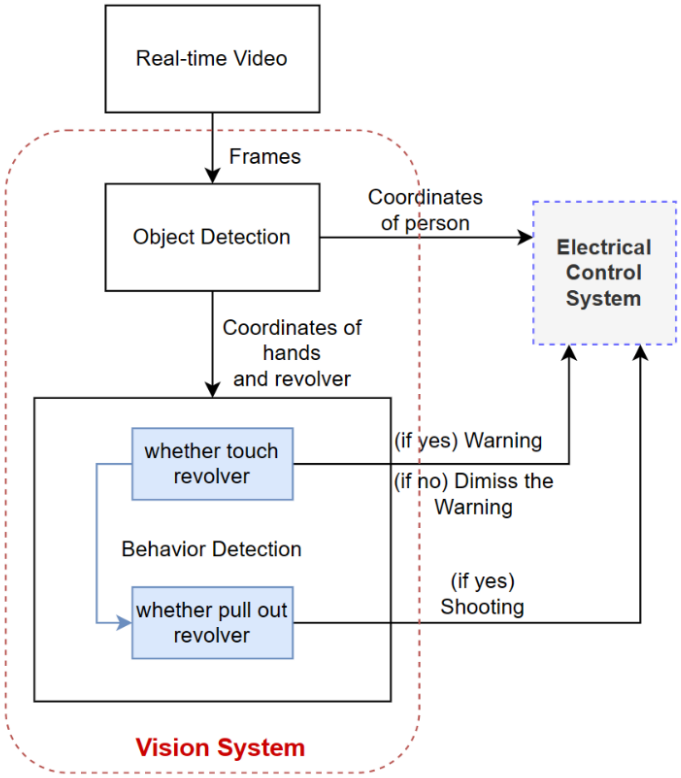
2. If the opponent's hand moves close to or touches the revolver on his waist, the robot should draw the gun and aim it at the opponent without firing. If the opponent gives up drawing a gun and surrenders, the robot should put its gun back in place. Otherwise, the robot will shoot at the opponent immediately. The detection will continue, and the robot will make an action right away if recognizing any suspicious movements until the person is out of the sight.

3. The opponent may walk around, the robot should adjust the direction according to the position of the opponent, so that it is always facing the opponent head-on to avoid being attacked from behind. Robot’s revolver should also aim at the opponent accurately.

2 Design

2.1 Block Diagram





2.2 Block Description

2.2.1 Electrical Subsystem Overview and Requirement

Electrical subsystem is a signal management and dispatch center. It connects with vision subsystems and Mechanical subsystems. The center of Electrical subsystem is a STM32 development board [2]. It receives messages from vision subsystems by Universal Asynchronous Receiver/Transmitter (UART) [3]. After processing the vision signal, it will send signals through Controller Area Network (CAN bus) [4] to Electrical Speed Controller (ESC) in order to make accurate movement. The control algorithm for the motor motion is Proportional–Integral–Derivative (PID).

1. Control unit can receive messages from the vision subsystem clearly with low delay.
2. Control unit can transmit signals to ESC clearly with low delay.
3. Control algorithm's accuracy for the motor motion should within 0.1 deg
4. It should have safety stop mode in case of emergency to keep users' safety

2.2.2 Vision Subsystem Overview and Requirement

Vision subsystem plays a role in recognizing the person with a gun, tracking the position of the person, and identifying his behavior. The input of the subsystem is the real-time video from the camera. And the output of the subsystem is the coordinates of the opponent and warning/shooting instructions which are sent to the Electrical Control Subsystem. Frames are detected one by one, the Object Detection Unit will output the coordinates of the hands, revolver, and the person. The coordinate of the person helps the robot to track the person in real time, while the coordinates of the hands and revolver is used for behavior detection/action recognition [6]. If either of the hands get too close to the revolver, it will be considered as 'suspicion of shooting', so the subsystem will send the warning instruction to the Electrical subsystem. If next, the hand moves away from the revolver, dismiss the warning. Else if the hand pulls up the revolver, it will be considered as 'ready to shoot', the subsystem will send the shooting instruction to the Electrical subsystem.

1. This subsystem must finish detecting in a short time to avoid a long delay.
2. The frames from the camera should have enough clarity to recognize the revolver.

2.2.3 Power Subsystem Overview and Requirement

Power subsystem should convert 220V AC input to 24V DC and 5V DC output. 24V DC is used to drive STM32 and motors. 5V DC is used to drive Jetson nano.

1. It should function properly with 220V AC power supply in China.
2. It can concurrently supply 24V 10A and 5V 5A with thermal stability.
3. It should have overcurrent and short circuit protection for safety.

2.2.4 Clamping Subsystem Overview and Requirement

The function of clamping subsystem is to grab and shoot the gun. This subsystem consists of a clamp to fix the gun with the robot, and two motion bars to move the hammer and pull the trigger. The grab motion should be fast enough.

1. The connect of the clamp and the gun should be strong enough
2. The mechanical structure should be light and easy to move.

2.2.5 Locomotion Subsystem Overview and Requirement

The function of Locomotion subsystem is to move the clamp and aim the gun. This subsystem consists of a three-degree-of-freedom robot arm and three 3508 stepping motor which is also part of electrical subsystem. It should move and aim faster than human.

1. The structure should be strong enough to sustain the inertia of high-speed movement.
2. The structure should be light to reduce the inertia when moving.

2.3 Risk Analysis

Electrical Subsystem: Since motion control and vision signals are both real times, the Electrical subsystem should have the ability to manage both side signals and that means we should implement a multi-thread system in the STM32 which is a challenge for us. And the signal transmission delay should be paid high attention due to the High Noon Sheriff Robot being a quick response robot.

Vision Subsystem: The detection of the objects and behavior with sufficiently low delay will be challenging for us because the robot needs to respond fast.

Clamping subsystem: Because of the high risk of the gun, the Clamping mechanism must be strong enough that the gun will not detach from the arm. But at the same time, the clamping mechanism is at the end of the mechanical arm, its self-weight will bring a very large motion inertia, which would affecting the aiming. Therefore, it is the biggest difficulty to balance the strength and weight of the clamping structure.

Locomotion subsystem: The motion subsystem should be both fast and accurate. To increase the accuracy, the tolerances of the moving mechanism must be precise enough. Additionally, the motion structure should bear high inertia, which would make deformation of the structure, on this account, the material of the structure should have high yield strength. Conventional 3Dprinting technology cannot achieve the above two requirements, so the selection of materials and processing methods will also be risking.

3. Ethics and Safety

When designing a system that involves physical components, it is essential to consider the potential harm it may cause to humans. The IEEE and ACM Code of Ethics emphasizes the importance of protecting human safety, and this applies to the design of such systems [5]. To ensure that the toy gun does not harm humans and the robot does not aim at fragile components like eyes, designers must implement safety features such as limiting the range of motion of the robot or adding sensors to detect nearby objects. Additionally, when conducting experiments involving such systems, it is crucial to wear appropriate safety clothing.

The mechanical system of the robot must also be designed with user safety in mind. The structure should be sturdy enough to handle unexpected movements of the motors, and the control system should have a safety loop that can cut off power before any risk occurs. These safety measures are in line with the IEEE and ACM Code of Ethics' emphasis on preventing harm to users [5].

Another ethical consideration in designing such systems is privacy concerns. For example, a camera may be used to identify a human's position and behavior, but this may raise privacy concerns. The IEEE Code of Ethics emphasizes the importance of protecting the privacy of others [5]. To address this issue, designers can isolate the vision subsystem from other subsystems and store the video in a secure location that can only be accessed with authorized certification. By doing so, the vision subsystem only sends coordinates and behavioral assumptions to the control system, and users are notified about the use of the camera and the information collected.

Since our design has both mechanical parts and Electrical parts, we should consider the safety issues related to mechanical and electrical parts. For the mechanical part, we should consider the safety for the moving parts, we should make sure that it will not hurt users and have an emergency stop in case of some situation to stop the moving system in a second. And for the Electrical part since we are dealing with 220V AC power supply, the electrical circuit should follow the principle of separating the high AC power and low control DC power into two individual systems and make sure they would not interfere with each other to prevent potential safety issues. In this case, we can make sure of the safety issue with both mechanical parts and electrical parts.

References

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