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Inspection Robot of Industrial Park Plant Based on Deep Learning

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Abstract: *With the continuous development of modern industrial plants, the demand for traditional manual inspection is increasing. Robotic inspection, as an efficient and accurate alternative, can significantly improve inspection efficiency and reduce labor intensity, while reducing potential safety risks. The goal of this project is to develop a robot based on multi-sensor fusion and SLAM algorithms that can autonomously perform inspection tasks in industrial plants. The robot is equipped with multi-functions such as pedestrian detection, accident detection, and automatic meter reading. At the same time, we will develop an app that connects to the robot's system, through which industrial park staff can remotely control the robot, view water and electricity meter information, and receive alert messages from the robot in a timely manner. This integrated solution will effectively enhance the intelligence level of industrial plants and provide more convenient tools for the management and maintenance of the production environment.*

Keywords: *Ros; Yolov5; Src Algorithm; Path Planning*

1. Introduction

With the rapid development of the economy, intelligent parks gradually appear in people's sight. The construction of intelligent parks has brought a series of conveniences to people, however, at this stage, the inspection work of intelligent parks still relies on manual completion, which has problems such as large labor costs, low efficiency, and difficulty in meeting the needs of digitalization, real-time, intelligence, and security of intelligent parks. At the same time, wrong or inadequate manual inspections may also bring serious safety and production problems, such as in April 2021, a gas explosion in a coal mine in Guizhou Province, China, killing 10 people, and it was reported that the accident may be related to the failure of manual inspectors to detect an abnormal gas concentration; and in December 2020, a fire in a flour mill in the Punjab province of Pakistan, killing at least eight people. Preliminary investigations indicate that the fire may have been related to the failure of manual inspections, which led to an equipment malfunction that triggered the fire.

In order to solve these problems, we propose the use of industrial plant inspection robot for inspection, to realize the timed inspection of the plant and to eliminate the occurrence of dangerous factors in the plant, such as fire, explosion, toxic gas leakage and other accidents. This robot is equipped with a variety of devices such as sensors, cameras, face recognition technology, etc., to realize automatic meter reading, accident detection, personnel clocking, pedestrian detection, etc., so as to realize automation and intelligence, reduce labor costs and inspection time, and at the same time, improve work efficiency and safety. The application prospect of this technology is broad, and it has important application value and promotion significance in the field of intelligent park and intelligent manufacturing.

2. Industrial Park Plant Inspection Robot System Introduction

As technology continues to evolve, the need for safety and efficiency management in industrial parks is becoming more and more prominent. In order to enhance the overall safety and productivity of industrial park plants, we have elaborated an inspection robot system that makes full use of deep learning and advanced technologies. The following are the key features of the system and the research results achieved:

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2.1 Face recognition system

2.1.1 Research background

Facial recognition technology is a key security measure in industrial parks. Face recognition technology is commonly and widely used in people's daily life, such as video surveillance, device locks for smart devices and so on. Although face recognition technology is relatively mature in the case of unobstructed and undamaged face images; however, in industrial parks, where masks and facial ornaments are common, the recognition effect of partially obstructed faces is not good.

2.1.2 SRC method

We found that Sparse Representation Based Classification (SRC) can be applied to face recognition. SRC has strong recognition ability, and it can complete the classification and recognition of data samples with the presence of occlusion, illumination, and posture changes, but the accuracy of the recognition decreases to varying degrees with the changes of occlusion area, illumination, and photo angle. However, the recognition accuracy decreases with the changes of occlusion area, illumination, and photo angle to different degrees. Therefore, we propose a multi-scale dictionary learning SRC method to solve this problem.[1]

2.1.3 SRC methods for multi-scale and deep learning

By introducing the SRC method with multi-scale dictionary learning, we have achieved a significant improvement in the representation capability and robustness of face images. The method decomposes the original image into sub-images at different scales and fuses these sub-images through deep learning to obtain a more discriminative representation. Experiments demonstrate that our multi-scale SRC method achieves significant advantages in both recognition accuracy and robustness compared to the traditional single-scale SRC.

2.2 Safety helmet testing technology

2.2.1 Research purpose

In order to improve the safety and inspection efficiency of the robot, we introduce a helmet detection technique based on improving YOLOv5. This technology determines whether a helmet exists in the image through target detection, which basically meets the mean value accuracy requirements for helmet wearing detection in industrial park scenes, thus ensuring that the staff always wear helmets during inspection.[2]

2.2.2 Application of YOLOv5 algorithm

We have used YOLOv5 algorithm as the basis for helmet detection and K-Means++ algorithm for anchor frame clustering of targets in the dataset. It was also trained with a large number of datasets and data enhancement techniques to improve the generalization ability of the model. It provides an important safety guarantee for the application of robots in industrial parks.

2.3 Path planning algorithm

2.3.1 Algorithm fusion

In order to improve the robot's navigation capability, we have thoroughly studied and improved the path planning algorithm by adopting a method that incorporates the improved A* algorithm and Bézier curve optimization. While we retain the advantages of the A* algorithm, we make the path smoother and more reasonable through Bezier curve optimization, which significantly improves the safety and driving efficiency of the path.

2.3.2 Better adaptive path generation

Our improved algorithm is based on the A* algorithm and introduces Jump Point Search (JPS) for heuristic function improvement, which improves the efficiency of path planning.[3]

The improved algorithm also performs global path smoothness optimization via Bessel curves. This optimization method makes the path more coherent, reduces sharp turns and jerks during the robot's path travel, and improves the overall travel comfort and stability. This integrated path planning scheme not only improves the quality of the path, enabling the robot to traverse the industrial park more efficiently, but also enhances the adaptability of the algorithm to better cope with various terrains and environments.[4]

2.4 Manipulatable cell phone software

We have developed a cell phone software that realizes real-time monitoring, data display and remote control functions for the inspection robot. The monitor can always understand the operation of the robot, display the index parameters and implement the work data, remotely adjust the robot's traveling route, ensure that the robot can timely deal with emergencies, and improve the safety management level of the industrial park.

Through these studies and applications, our industrial park plant inspection robotic systems are able to achieve significant improvements in safety, efficiency and reliability, providing advanced safety management and productivity solutions for industrial parks.

2.5 Fire detection and gas concentration detection

2.5.1 Application of infrared sensor

In our fire detection and gas concentration detection system, we make full use of advanced infrared sensor technology, which plays a key role in the safety management of industrial parks. The implementation process and key functions of this system are described in detail below:

2.5.2 Technical realization

We have chosen highly sensitive infrared sensors as the core components of the system. These sensors are capable of capturing the infrared radiation signals generated when gases such as fire and gas are released. The sensors were selected based on their ability to quickly and accurately detect these hazardous situations under different environmental conditions, ensuring that the necessary safety measures are taken in the shortest possible time.

2.5.3 System workflow

The system first monitors the environment of the industrial park in real time through infrared sensors. Once the sensors detect a fire or gas concentration above a set safety threshold, the system triggers a rapid response mechanism.

2.5.4 Fast response mechanism

The system will immediately send out an alarm signal and at the same time transmit the detected data to the central control center. The central control center can obtain detailed information about the fire or abnormal gas concentration in real time and take appropriate emergency measures, such as activating the fire extinguishing system, notifying the relevant personnel to evacuate, or working in concert with other safety equipment.

2.5.5 Data recording and analysis

The system is also equipped with data recording and analysis functions. By storing historical inspection data, we are able to conduct after-action analyses to understand the pattern of fire or gas concentration abnormalities, providing strong support for future safety improvements.

2.5.6 Visual interface

Our system uses an intuitive visualization interface to display the current environmental status in the form of charts, graphs and real-time monitoring videos. This allows operators to quickly understand the security status of the industrial park and helps to formulate and adjust security strategies in a timely manner.

2.6 Meter reading system based on R-FCN algorithm

We introduced a meter reading system based on the R-FCN (Region-based Fully Convolutional Networks) algorithm, a choice that not only emphasizes the accuracy of target detection, but also offers multiple advantages in coping with meter dial readings.

One of the advantages of the R-FCN algorithm is its superior performance in target detection. Compared to traditional target detection methods, R-FCN achieves higher detection accuracy by using a combination of Region Proposal Network and Fully Convolutional Network in the image.The R-FCN

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algorithm uses ResNet-based FCN as the base network, and compared with other deep network models such as AlexNet, ZF [59], VGG and GoogleNet, ResNet has a residual structure that does not generate additional parameters to increase the computational complexity, and can effectively alleviate the gradient vanishing and training degradation problems of deep network training, thus improving the convergence performance of the network.[5]

3. The innovation point and characteristic of this system

3.1 Improved A algorithm and Bessel curve optimization path planning algorithm*

This improvement is based on the A* algorithm to study the path planning of AGVs, using the improved algorithm of A* algorithm, jump points search (JPS), to improve the illuminating function, so as to reduce the unnecessary memory occupation in the Open_list and the Close_list, and at the same time greatly reduce the algorithm's calculation time, and then optimize the global path smoothing through the Bézier curve. Bézier curve is used to optimize the global path smoothness.[3]

3.2 Application innovation

This project designs a mobile app with an inspection robot, which realizes remote monitoring and management of the robot and provides several intelligent services.

The mobile App can communicate with the Raspberry Pi on the robot's vehicle to obtain real-time data from the vehicle's camera, as well as inspection data on face recognition, helmet detection, outsider detection, fire monitoring and so on. Through the App's real-time monitoring function, users can keep abreast of the status of the industrial park plant, find abnormalities and take timely measures. In addition, the App can also improve safety and warning effect by sending alerts to users.

3.3 System characteristics

3.3.1 Multi-sensor fusion technology realizes robot route planning and obstacle avoidance

Today's vision SLAM systems for dynamic environments have a fatal drawback: when there are multiple moving objects in the environment, the system cannot tell if the machine itself is moving or if the objects in the environment are moving. This leads to inaccurate localization information, which prevents the robot from avoiding moving objects properly. This problem can be solved by using multiple sensors.[6]

The first is GPS, which is usually used in practical applications, but it provides centimeter-level accuracy for the machine, but because the update frequency is too low to allow the machine to follow the desired trajectory, it is often necessary to introduce new sensor signals in order to increase the machine's positioning frequency. Inertial sensors, on the other hand, have a positioning error that grows over time, but because they are high-frequency sensors, they can provide stable real-time position updates over short periods of time. So by fusing the advantages of these two sensors and taking the best of each, a more real-time and accurate positioning can be obtained.

However, this does not solve the problem of inaccurate localization in dynamic environments, as these two sensors are for wide-range localization, and we need the robot to be able to sense walls, pedestrians, objects on the floor, etc., when it is necessary to move a robot in a narrow room or corridor. This can be done by installing a camera on the robot to improve perception, or we can use LIDAR to accurately collect parameters such as distance, orientation, height, speed, attitude, and even shape of the target by receiving the reflected laser beam. If a machine utilizes multiple LIDARs at the same time, it can create highly accurate maps. The combined use of these sensors can be a good solution to the problem of visual SLAM systems being unable to accurately localize in dynamic environments.[6]

3.3.2 Fire detection and gas concentration detection technology based on infrared sensor

This system uses infrared sensor-based technology to design and realize a high-precision fire detection and gas concentration detection system. The system realizes the detection and early warning of fire and gas concentration by collecting the infrared radiation emitted by objects or gases and based on the absorption characteristics of objects or gases in the infrared band. The technology is characterized by high precision, fast response, all-weather monitoring, safety and reliability, etc. It can provide an efficient, accurate and reliable technical means for monitoring fire and gas concentration in industrial parks and

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plants, etc. At the same time, the technology can also be combined with other sensors and systems to realize automated, intelligent and unmanned monitoring and management of industrial parks and factories, and improve the productivity and safety of industrial parks and factories.

4. Summary

The research on industrial park inspection robots has made great progress, but there are still some problems in practical applications, such as the robot's accuracy, stability, cost and other aspects need to be further improved and perfected. Based on the above shortcomings, this project proposes to improve the A* algorithm and intelligent obstacle avoidance methods, which can make the industrial park inspection robot more adaptable to the complex and changing scenes, and add the functions of pedestrian detection and table checking, etc., and proposes to design the corresponding interactive APP, which can make the work of the industrial park inspection robot more efficient and easier for the workers to control.

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