Deep Learning and Embedded Based Operational Safety System for Special Vehicles

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Abstract

Aiming at the characteristics of special operation vehicles, such as complex operating environment, heavy vehicle weight, long braking distance, and many visual dead angles for drivers, this project designs and implements a special vehicle operation safety system based on deep learning and embedded system. Firstly, the deep learning model is applied to detect the humanoid target appearing around the vehicle, get the detection frame of the humanoid target, and estimate the distance from the target to the camera; using the advantage of the embedded system which is relatively small can be easily deployed on the heavy vehicle. According to different distances, the system will issue relevant voice prompts to remind the driver to take timely measures such as avoiding or braking.

Keywords：special operation vehicles，Deep Learning，Embedded system，Complex working.

1. Introduction

Blind spots in the field of vision of specialised vehicles during operations are a serious safety challenge that can lead to a wide range of accidents, as the vehicles tend to be large-bodied. These drivers may not be able to directly observe the blind spots in their field of vision, increasing the risk of hazards to workers, other vehicles and obstacles.

For example, in specialised vehicles such as excavators or loader trucks (Fig. 1 below). drivers may not be able to directly see pedestrians or workers around them due to the special construction of the equipment itself, increasing the risk of run-over or collision accidents. In addition, when turning, working or reversing, the blind spot in the field of vision may also result in the driver not being able to perceive other vehicles behind the side, which may lead to a collision accident. Drivers are also less likely to be aware of fixed obstacles such as rocks and pillars, which can lead to collisions [1].

Fig. 1 Common Heavy Vehicles

In order to counteract these risks, specialised vehicles can take appropriate measures. To this end, we have designed a system that helps drivers to better avoid and detect obstacles in a timely manner, for example by installing auxiliary cameras and sensors. The use of advanced assistance systems, the strengthening of the driver's field of vision and the incorporation of a hazard warning system reduce the probability of safety accidents caused by blind spots or obstacles in the field of vision of specialised vehicles during operations [2].

The rest of this paper is organised as follows. Part II describes the hardware usage scheme. The third part describes the innovative points of the design as well as the leading advantages. The fourth part explains the application scenarios using the design. Part V summarises the main points of the paper.

2. Hardware usage programme

2.1 Jetson nano

Hardware selection, we take into account the cost-effectiveness and durability of the two major aspects of the main development board selected NVIDIA series of development boards - Jetson nano development board.

Here to introduce this development board type: Jetson nano is NVIDIA's development of high-performance GPU equipped with a microcontroller, is to achieve deep learning and parallel computing necessary microcontroller. It is broken down into four different types of development boards. They are: Jetson Nano, Jetson TX, Jetson Xavier NX, and Jetson AGX Xavier, where we choose Jetson Nano. Because of its low energy consumption and low cost it takes the lead among the other three microcontrollers. And its arithmetic power has been increased by tens to hundreds of times, even more than a small part of the current computer CPU, and NVIDIA also equipped with a full set of SDK for it. the following Fig. 2 is the picture of Jetson Nano development board, Fig. 3 is the development board core board [3].

Fig. 2 Development Board

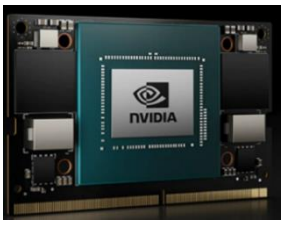

Fig. 3 Core Board

The jetson nano performance metrics (representative) are shown in Table 1.

Table 1 jetson nano performance metrics

arithmetic power	40TOPS
GPU	1024-core NVIDIA Ampere architecture GPU with 32 Tensor cores
CPU	6-core Arm® Cortex®-A78AEv8.2 64-bit CPU 1.5MB L2+4MB L3
RAM	8GB+68GB
Camera Interface	2 CSI interfaces
output	5W-10W

2.2 surveillance camera

Cameras are generally selected industrial cameras, such as Hikvision cameras or select Dahua cameras. The advantages of these two cameras are high-definition, clear images, large shooting angle, can be rotated and in the dim light conditions, has a strong night vision effect. They provide a more accurate video feed to the central processor. Fig. 4 below shows the Hikvision camera shooting debugging screen.

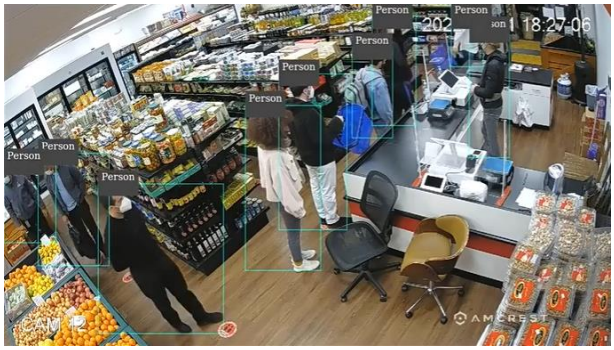

Fig. 4 Debug screen

3. Innovative design and advantages

3.1. *Deep Learning*

The initial idea of our design is to first recognise the human figure, and then to warn the driver by triggering an alarm when the human target walks into a relatively dangerous area of the vehicle's operation.

Due to the relative complexity of the special vehicle operating environment, traditional computer vision and image processing algorithms are relatively fuzzy and difficult to deal with to identify the humanoid target from the environment, and often triggers the alarm system incorrectly (e.g., a roadblock or reflective clothing), therefore, deep learning models are used in this project to complete the identification of the humanoid target, which is shown in Fig. 5.

Deep learning is a research direction in the field of machine learning. Deep learning uses deep neural networks for modelling and uses large amounts of data to optimise the parameters in the model to achieve high accuracy and robustness.

We have designed a deep learning model that can recognise targets within 50 to 100 metres in terms of distance, up to 9000 types of objects (yolo-9000) in terms of type, and hundreds or even thousands of targets in a single frame at the same time.

Fig. 5 Initial identification of deep learning models

3.2. *Technical difficulties*

There are many types of special vehicle operating scenarios such as harbours, construction sites, mining sites, as in Fig. 6. intensive construction of people, many obstacles and close vehicle traffic. Sand, gravel, goods, and materials are piled up. These serious obstacles to our acquisition of the surrounding image information.

Fig. 6 List of construction scenes at mines and construction sites

In addition, because it is assembled on the carrier, it is required to have low energy consumption; and the space inside the vehicle is narrow, which can only accommodate smaller equipment for normal operation, so we can only compress its size.

Due to the ever-changing environments in complex places, we cannot predict what will happen next. So we need as little false recognition or frame skipping as possible. Too many misjudgements can cause unnecessary distractions for the driver. In addition, if the vehicle is travelling fast in a complex scene, there may be a requirement for the real-time performance of the model.

Generally in complex scenes there will be a large number of staff and supervisors. We want to recognise and estimate their distance to their own vehicle as much as possible.

3. 3. *Problem-solving responses.*

For the human-type and object-type densification problems, we have prepared datasets for training. A certain amount of data is collected to form the dataset for training and the dataset for testing. The amount of data is usually 2000 images, which contain at least 5000 humanoid targets. The dataset is labelled using manual annotation (Fig. 7). At the same time, the surrounding environment is constructed (Fig. 8).

Fig. 7 Dataset labelling

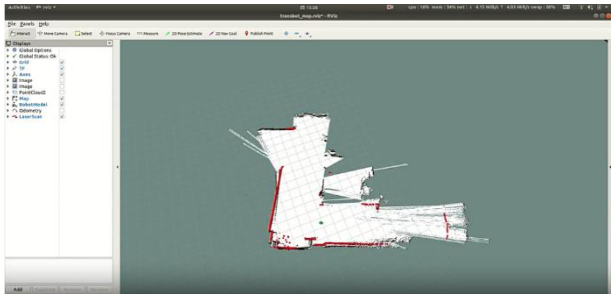

Fig. 8 Environmental scanning

The mainstream deep learning yolov5 and the deep neural network Pedestrian net, which is specialised for humanoid and vehicle detection, are deployed on jetson nano [4].

The model uses ResNet34 as the basic underlying layer and combines advanced techniques such as feature fusion, local zoom, and exact query. The original model is 84.62MB, after pruning 7.85MB, then use Tensor RT for assisted optimisation, generate the physics engine in

semi-precision form, and then deploy the physics engine into deep learning, then after a series of operations can be done on a development board to deal with four to eight video signal sources.

Finally, the target detection metadata is sent in the form of a request to the thread responsible for estimating the distance and voice announcement, and multiple calculations are performed to compare the estimated relative distance with a pre-set threshold to minimise the impact of erroneous judgements. Finally, an alarm is triggered to warn the driver to be careful of the surroundings.

4. Job Scenario Application.

4.1. *yard operation*

Heavy vehicles loading and unloading in port yards face serious visual challenges, with a large number of visual dead zones and blind spots. At the same time, the construction site is a noisy environment with a large number of people, which makes it difficult for the driver of the operating vehicle to detect people in the vicinity of the vehicle in a timely manner in complex situations, thus spawning many safety hazards.

We use a four-channel video signal source to assist the operation. The four video sources are processed simultaneously on a single jetson nano, which can achieve 10 frames per second for each source. The communication is done through a pos switch and finally a voice alarm system.

4. 2. *Shield Tunneling*

Shield Tunnel Battery Vehicle is an electric vehicle specially designed for shield tunneling project, and its main task is to transport materials and transfer personnel at the tunnel construction site.

However, due to the poor line of sight in the tunnel and the heavy load of the vehicle, there is a great safety hazard in the construction. The main reasons include: the existence of a blind field of vision, the existence of a no-signal section in the tunnel, the absence of reminders during operation, the possible failure of the brakes, and improper operation.

We made a solution to these situations in the follow-up processing, first of all, the tunnel front and rear of about fifty metres distance sweep, the construction workers to collect data, and then through our are reinforcing the night vision effect algorithm will be the situation in the tunnel for light reinforcement, passed to the pos switch, and finally complete the exploration of the environment around the shield tunnel machine. Fig. 9 below shows a comparison of the colour of the enhanced picture in dark conditions for the night vision effect.

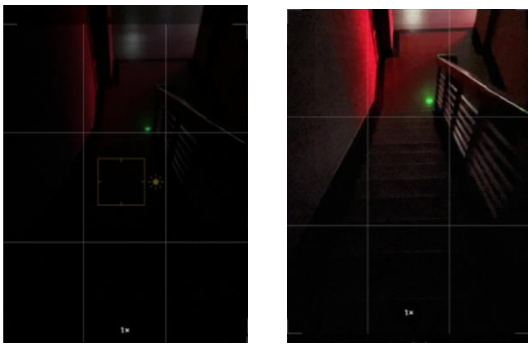

Fig. 9 Night Vision Enhanced Picture Colour Before and After Comparison

Fig. 10 below shows the final physical model drawing and the final physical picture.

Fig. 10 Physical models and final objects

5. Synthesis

This paper describes the various safety hazards of specialised vehicles in complex situations and how to deal with them. A machine has been designed to assist special vehicle drivers to avoid accidents. It can be adapted to various complex sites including yards, harbours and mines. By coping with various conditions

with ease. It is believed that in the future, it can help more drivers and escort the safe operation of special vehicles.

6. References

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Authors Introduction

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