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Hardware Acceleration of Real-time Image Processing for Vehicle Control

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Keywords: Hardware Accelerator, GPU, Programmable logic, Embedded system.

1 Introduction

Nowadays, the computers or laptops that we use in our daily life can handle the most of programs. Even for some applications that involve high computational intensity, our computers can execute program without any problem. However, in the small electronic devices such as smart phones, executing high computational intensity programs is not suitable. The reason behind this difference is the processing power. In computers or laptops that we use, mostly, they already contain the hardware accelerator to handle high computational intensity program while embedded systems don't have.

The autonomous car is a vehicle that can navigate and drive without human interference. The vehicle must have the potential to analyse the environment information from the sensors. The environment information is retrieved in various format such as the video from camera, the data from sensor and so on. The enormous of environment information must be processed as fast as possible in order to respond to the environment. In this research,the road surface marking is chosen as a target program for acceleration. The road surface marking is commonly used in the autonomous car for keeping the vehicle to the lane.

The aim of this research is to implement the hardware accelerators for the road surface marking program on virtual environment. The hardware accelerator should be able to accelerate the road surface marking program while remain the capable of tracking. The road surface marking program is executed in the virtual environment to simulate the environment information. In order to solve the problem, this research purposes the methods for the hardware accelerators. Two bases of the hardware accelerators are GPU base hardware accelerator and PL base hardware accelerator. we purpose the virtual environment system which is implemented to simulate the real environment.

2 Virtual Environment System

The process of developing the embedded system requires the real embedded devices to operate the applications. However, the development under the real circumstance is not

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appropriate in some applications, especially, for the system that interacts with human. The errors from slight mistake can threaten someone's life.

Virtual prototyping is one of the methods to simulate the real environment. The real environment of the target embedded system is simulated by hardware and software. By doing this, the system can be developed even if the system is not operated under the real circumstance.

3 Road Surface Marking Program

In order to research the effect of acceleration, we have to choose the target program to be accelerated. The target program should be a computational intensive program because the result from the acceleration is more obvious than the less computational intensive program. In this research, a road surface marking program is chosen to be the target program of acceleration.

The road surface marking is implemented by using the image processing algorithm to distinguish the interested objects from the image. The interested objects must have the specific features so the algorithm can distinguish it.

4 Hardware Accelerators

The computation resources such as central processing unit (CPU), memory, input-output ports, and so on, in the embedded systems are dramatically less than workstations and desktop PCs. Therefore, designing the high intensive computational programs in the embedded systems is different from that for workstations and desktop PCs. Moreover, in general, the embedded systems are used in an interaction environment. The responsiveness is one of the major concerns in the embedded system.

In this research, the interested embedded system is the vehicle controller system. The navigation program, which is a road surface markings program, should respond to environment fast enough. Even though the road surface markings program is not highly compute-intensive program, it's response in embedded system is not fast enough to be used in the real-time environment. The CPUs processing in the embedded device is much less processing power than CPUs processing in the workstation. Thus, in order to achieve the real-time response, the system requires an accelerator. The software accelerators require no add-on components but they have the limitation of acceleration. On the other hand, the hardware accelerators provide much more acceleration factors than the software accelerator. However, the acceleration of the hardware accelerator depends on the hardware components that are used to accelerate. In this research, the graphics processing unit and programmable logic are used as the hardware accelerator.

5 Experimentation

In this research, the hardware accelerators are implemented based on two types, which are GPU and PL. The evaluation of hardware accelerators are completely separated because

of the hardware difference between Jetson Tegra K1 for GPU based and Zedboard for PL based implementation.

In the experiment, the image information is retrieved from the Windows game simulator. The image is cropped from the full 1280 width and 720 height to 1280 width and 300 height because the road surface marks are located in lower side of image. Then, the hardware accelerators are experimented by processing the cropped images. The performance is evaluated in terms of execution time per frame. The execution time per frame is retrieved from the average execution time.

6 Conclusion

The hardware accelerators are effective in achieving a higher performance. In this research, the system is accelerated by using two based type of the hardware accelerators. Firstly, GPU based accelerator is implemented in Jetson Tegra K1 with the overclocking method. Lastly, PL based accelerator was implemented in Zedboard.

In conclusion, the virtual prototype of the vehicle controller system, which implements the road surface marking, can simulate real-time environment, in term of the responsiveness. The hardware accelerator is able to accelerate the road surface marking while remain the capable of tracking.