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FPGA Implementation of Driver Assistance Camera Algorithms

Design Issues

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Introduction

Safety has increasingly become the key determining factor for several consumers in choosing one car brand over another. As a result, vehicles from an increasing number of automakers are being more and more attentive to their surroundings than drivers operating them. With today's technological advancement, Driver Assistance System has become the fastest growing area in the automobile industry. These systems aim to alert and help the driver in its driving process. Examples of such system include Lane departure warning and Collision avoidance systems. One of the rising research areas in Driver Assistance is the use of cameras combined with robust image processing algorithms to visually alert the driver of objects that might constitute hazards. Due to the nature of this task, real time image processing requires the algorithm to be time efficient. FPGA (Field Programmable Gate Array) devices are designed to provide massive DSP functionality by taking advantage of hardware parallelism. Given the ability to control inputs and outputs at the hardware level, faster response time and reduced software-driven tasks are the main reasons why several automotive engineers are choosing FPGA (Field Programmable Devices) devices as a cost effective way to develop and produce new Driver Assistance products.

With the sponsorship of Xilinx, our team's mission is to provide an FPGA implementation of an object detection algorithm using input images from a rear view camera. The idea is to alert the driver of potentially hazardous objects seen within the camera. In our development process, we considered a broad set of issues. The main issues discussed are Product Lifecycle Management (PLM), Universal Design, and Product Liability.

Product Lifecycle Management

The Product Lifecycle Management (PLM) is the process of planning how to create a product from the conceptual stage through the recycle and reuse stage. The stages of PLM include concept, design and develop, production, distribution, consumption, and end of life. All phase of PLM were carefully considered with design, production, distribution, and end of life being the most important areas for this project.

Design and Development

The proposed algorithm is being implemented on Xilinx's Xtreme Spartan 3-A DSP board. This is a development board so there are many extra features on this board that the proposed design would not utilize. If this system were to be developed for large scale production then a smaller more efficient board would need to be created to cut down on cost, size and efficiency. This is the only hardware component that needs to be designed when this project is produced for the mass market. With an FPGA system most of the hardware and software is implemented inside the chip so limited hardware is needed for production.

This project is mainly a software project so the performance of the algorithm is the largest issue. The algorithm has been carefully created to ensure accuracy and speed. One aspect that took careful consideration was in the edge detection algorithm. It was decided that performance over accuracy was more important. The video could not have any delay so the decision to use the Sobel edge detection was chose. This would provide enough accuracy while showing no delay. The algorithm for this project will have multiple updates in the future. When this project goes into production it might only have object detection. There are many more features, other than object detection, that this system will have. Many of the consumers who receive the first generation of this project are going to want the newest release with the extra features. If the Spartan 3-A DSP development board were to be used in the car, then this system would easily be upgradable each time there is a new release. Since size and cost are issues a development board cannot be used. There will have to be a medium between the development board and a minimal cost board where future updates can be installed, while still keeping cost down.

At the present time there are no standards relating to active safety devices on automobiles, however if the system can be updated then future standards won't be an issue. It is rumored that

in 2014 government agencies will mandate all new vehicles to possess back-up cameras. Since vehicles are lasting over ten years the proposed design has to anticipate what sort of standards might come with this law being passed. With a proper design the system would confine to all standards set forth. If the system is upgradable then a new algorithm could be installed to comply with the future laws.

Production and Distribution

The goal of this product is to distribute it to OEM manufacturers like Ford, Chryslers, or Toyota. These automobile companies will need to see the benefits of using this system over the one that is already implemented in their vehicles. If manufacturers decide to use this rear view camera system then it will be another part that will be installed when manufacturing the vehicle. For OEM's that won't cost them any extra money. To meet the demands for manufacturers this product will have to be mass produced to possibly be installed in millions of vehicles. It will have to be cost efficient and easily producible for manufacturers to buy this system.

Reuse and Recycle

If a board is created where future updates can be installed this product will be reused through the life of the car. There is not a problem with the durability of the system, the only issues of interest is will better technology replace it. This system has to keep up with the longevity of automobiles to ensure it will not become out of date. This system could easily be reused between automobiles if it stays up-to-date. This will all rely on how well the hardware is designed and the advancement of the algorithm. If this product needs to be recycled that will not be an issue because there are no harmful materials in it.

Universal Design

Universal design is an important part of any project. It can best be defined as designing a product to ensure that the product does not limit itself to only being targeted to individuals who are fully able. Not only can it give your company a bad reputation, but also there are many regulations in place that require products to meet universal design standards.

Not taking consideration to universal design principles would be a costly error in the design process of our project. Taking a universal design approach for our project would ensure that the product we are developing would be equally accessible for individuals who are both able-bodied and disabled. Our project does not have any moving parts so it will be usable by people with various levels of motor skills. The main element of the project is the algorithm that will operate on the camera stream and the monitor that will display the output. The monitor needs to be able to accommodate individuals with sight problems. Brightness and contrast adjustments on the monitor will help those who have difficulty with vision. The algorithm itself can also present some issues. Object detection is the main goal of our project. To show that an object has been detected, we will be placing a box around the object of interest. The thickness of the lines used to box the objects will be an important factor in the ability of the user to know that an object has been detected. Making the thickness of these lines adjustable will help with this issue. The color of the lines used will also be important to make sure that users who are colorblind will be able to clearly identify the boxes. Adding an audible alert when an identified object is about to be hit will also expand the range of individuals who will benefit from this project. The tone of the alert must also be accounted for. Having the tone of the alert be adjustable will help with people who have difficulty hearing certain frequencies or are sensitive to certain tones.

Overall, our project will already benefit a broad range of individuals who are both able and disabled. Identifying the areas where our project can cause issues for those with disabilities and creating a solution for them, our project will be able to be targeted at a wider range of users.

Product Liability

Product liability is of primary concern in the FPGA Xilinx image processing device. The device is an active safety device, which means it aids the driver in preventing an accident. If not protected correctly legally, it could open the door to many lawsuits of potential accidents.

Another concern is a variety of signals interfering with the device in a multitude of different vehicles causing malfunctions. All of this is very critical to protecting the liability of the FPGA Xilinx image processing device.

In 2000, Ford Explorers' Firestone tires were failing and causing rollover accidents. This led to many lawsuits because of miscommunications between Ford and Firestone in addition to a failure to thoroughly test the vehicle in all situations. As press coverage of the controversy increased, public opinion affected not just Ford's Explorer brand but also reflected poorly on Ford Motor Company itself. Although this device most likely cannot actively cause accidents, a case could be made that an over reliance on a device which fails could cause an accident. The majorities of product liability laws are determined at the state level and vary widely from state to state. The FPGA Xilinx image processing device will be most vulnerable to strict liability cases. These cases do not require proof of negligence and in some states, such as California, can be targeted towards the makers of component parts installed in larger products. This is of supreme importance to Xilinx whose device would be installed in larger automotive manufacturers. In the past, many lawsuits target the larger company for more money, but under strict liability cases, this can be easily averted to target the specific failed component's company at fault.

The FPGA Xilinx image processing device will eventually be in an automotive vehicle with many other electronic signals. Proper testing by an OEM such as Ford or Toyota is paramount to the safety of the device. In 2010, Toyota had several recalls because of a rising complains in unintended acceleration. Although the definitive cause was never found, a prominent theory was the electronic throttle system. The thought was that the throttle system could either fail or pick up an ambient electronic system and malfunction. Another such recall was for anti-lock brake software. Recalls cost automotive manufacturers millions of dollars and a potential recall because of an FPGA would greatly offset any success of the device. An automotive vehicle has many signals and wires throughout the wire harness of the vehicle and testing all the functionality of the device in various conditions would be a costly one but ultimately cost saving.

Preventing a recall is worth the many hours of labor to ensure the safety and functionality of the FPGA Xilinx image processing device.

Conclusion

The process of designing new products often requires many issues to be considered for successful marketing. In the case of an FPGA Implementation of Driver Assistance Camera Algorithms, several design issues were taking into consideration; however, the main issues discussed were Product Lifecycle Management for design to effective recycling of the product, Universal Design providing accessibility to a broader range of customers, and lastly Product Liability to take aim at potential design and manufacturing defects.