Development of Flying Camera System Platform using FPGA

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In recent years, the Advanced Driver Assistance System (hereinafter referred to as ADAS) that detects possibility of accidents and takes evasive actions is rapidly spreading in the automobile industry. Surround view, which is one of the ADAS applications, is a system aimed at providing the driver with an overhead image looking down from a virtual camera above the vehicle. With this system, the driver can obtain a 360-degree field of view around the vehicle, so that contact accidents during parking and when starting to move can be reduced.

In the conventional surround view, viewpoint of the virtual camera was fixed at a position above the vehicle, therefore it was difficult to display a view specialized to the driver's action such as the traveling direction when starting to move. Hence, the virtual camera viewpoint has been improved to be dynamically and freely changeable resulting in the flying camera system.

Utilizing the FPGA (Field Programmable Gate Array) from co-creation partner Xilinx, OKI IDS (hereinafter referred to as OIDS) has jointly developed a platform for a flying camera system with Xylon. The platform overview and a demonstration system are presented in this article.

Xilinx is a U.S. FPGA vendor, and in 2013, OIDS has been certified as Japan's sole "premier partner." This certification is only given to companies that meet Xilinx's most stringent "technical capacity, business process, quality" standards.

Xylon is Croatia's FPGA IP (Intellectual Property) vendor, and the company globally deploys logicBRICKS*[1] IP core library and FPGA design service. They have a remarkable development record especially in the European and North American ADAS markets.

OIDS signed an agreement with Xylon for exclusive usage rights of the advanced driver assistance systems technology in 2014 making it possible to develop systems using Xylon's IP[1].

Surround View System

The surround view system uses high-speed, high-definition image detection technology and recognition technology to combine input images from multiple cameras attached to the exterior of the vehicle and generates an overhead image that is easy for the driver to see.

Photo 1 shows the overhead image of the surround view system. In order to generate this overhead image, four cameras are arranged in the front, rear, right and left directions of the vehicle as shown in **Figure 1**.

Photo 1. Surround View

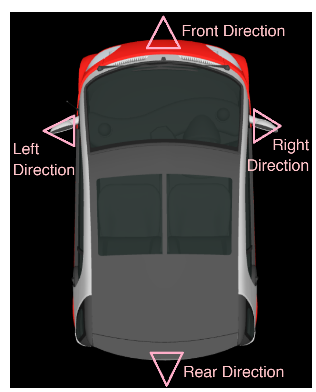

Figure 1. Layout of Surround View Cameras

In addition, each camera is mounted at a downward angle so that the surroundings of the vehicle can be easily monitored. **Photo 2** shows the mounting of the actual cameras. The front camera is mounted at the center of the vehicle's front grille, the left and right cameras are under the door mirrors, and the rear camera is mounted by the rear license plate.

*1) logicBRICKS® is a trademark of Xylon d.o.o.

Photo 2. Camera Mounting Positions

Although the surround view system combines the four camera images into a single image, the important problem lies in seamlessly combining the four images after absorbing the variations among individual cameras and mounting positions. In order to solve this problem, a lens calibration process is initially performed, and a correction value for each camera is determined.

Based on the correction values, images are combined in real-time.

Flying Camera System

The developed flying camera system allows the virtual camera viewpoint of the surround view system to be changed dynamically and freely. The system immediately generates an image of the vehicle surroundings using overhead images taken from arbitrary viewpoints/angles. Additionally, it provides a real-time overhead image from a virtual camera viewpoint selectable by the driver with an input device.

Figure 2 is a trajectory diagram of the flying camera system's virtual camera viewpoint. The crosshair with arrows in the figure represents the cruciform track of virtual camera viewpoint centered directly over the vehicle, and the circular line with the arrows represents the elliptical track. As the viewpoint of the virtual camera moves along the cruciform and elliptical tracks, it is controlled so its line of sight is always looking toward the center of the vehicle, no matter where in the track the virtual camera is positioned.

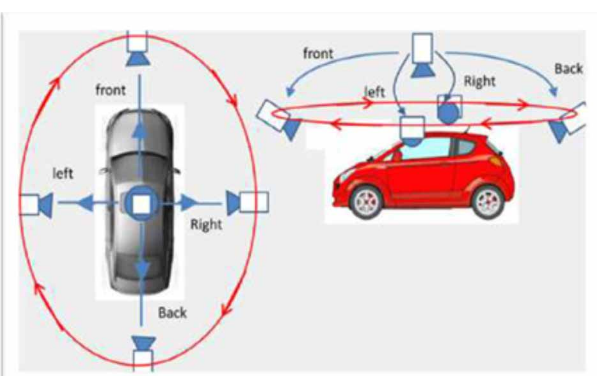

Figure 2. Virtual Camera Trajectory Diagram

*2) HDMI® is a trademark of HDMI Licensing LLC.

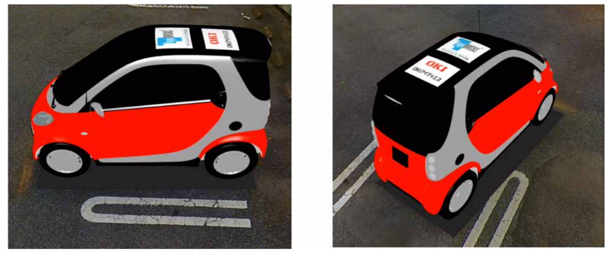

Photo 3. Images of Virtual Camera Viewpoint

Photo 3 shows overhead images of the virtual camera viewpoint when the position is changed.

Conventional surround view system was realized with lens calibration for image correction and calibration for image synthesis. However, the flying camera system adds "virtual camera viewpoint correction" to the "image correction," and this must be executed in real-time.

Furthermore, for the driver to view the overhead image in real-time without stress, the following functions and performances are required.

(1) Image input

The effective image size per camera should be 1280 pixels, 800 lines, and all effective images should be captured at a rate of 30fps (frames per second, hereinafter fps) in YUV422 format (resolution and frame rate equivalent to a HDTV).

(2) Image correction

Since a fisheye lens is used in the cameras, image distortion will occur. Therefore, each of the four screen images must be simultaneously corrected in real-time.

(3) Vehicle model rendering

A 3D vehicle model matching the virtual camera viewpoint must be generated in real-time.

(4) Image output

The image output should be via HDMI*2) interface with an effective image size of 1920 pixels, 1080 lines at a speed of 60fps in YUV422 format (resolution equivalent to a Full HDTV and frame rate of a game machine).

In order to realize these requirements, it was necessary to solve the following technical problems

- Need of a high performance CPU
- Improvement of processing performance through high-speed memory access
- Advanced image processing
- FPGA resource optimization
- Reduced load on software processing

Overcoming these problems with OIDS's FPGA technical design capabilities, platform for a flying camera system was built and implemented in a demonstration system.

Platform Overview

The platform utilizes Xilinx's latest FPGA device, Zynq UltraScale+ MPSoC*3) and Xylon's logicBRICKS IP core library, which synthesizes the four-direction fisheye camera images, to perform the dynamic camera viewpoint correction necessary for the flying camera system.

The logicBRICKS IP core library provides IPs for performing various image processing, such as logiWIN video capture IP for capturing images, logiVIEW video processing IP for image processing, and logiCVC-ML multi-layer compact display controller IP for image synthesis.

The platform overview is given below.

As the application processing unit (APU) for the FPGA, the Zynq UltraScale+ MPSoC EG device with a 1.5GHz Quad Core ARM*4) Cortex-A53 processor was adopted[2].

The high-speed processing that was achieved enabled memory to be accessed from a 64-bit data bus at a maximum of 1,067MHz.

Incorporation of Xylon's video processing IP helped in the advanced image processing.

The FPGA resource was optimized by packaging all usage ratios of LUT (Look Up Table), DSP and Block RAM to 20% or less.

Along with using the ARM Mali-400 MP2 for the graphics processing unit (GPU) installed in the FPGA to reduce load on software processing, technology for high-speed operation up to 667MHz was established to achieve high-speed processing.

Figure 3 shows the FPGA and main hardware components, and the function of each component is described below.

1) Images captured with the cameras are input as parallel data to the FPGA via the FMC FPD-Link III interface board. Then the data in the FPGA is loaded into external DDR4-SDRAM by the logiWIN video capture IP. Four logiWIN video capture IPs are used simultaneously for the front, rear, left and right directions.
2) logiVIEW video processing IP reads the images captured in 1). It then performs image correction, image resizing, rotation and integration of multiple images to generate an overhead image, which is stored again in external DDR4-SDRAM.
3) The GPU renders the vehicle model according to the 3DS format data of the external memory and stores it in the external DDR4-SDRAM.
4) logiCVC-ML multilayer compact display controller IP combines the overhead image and the vehicle model image. The output image from the FPGA is output to the monitor as parallel data via the FMC HDMI interface board.
5) The viewpoint conversion of the virtual camera is done by software application running on ARM Linux.

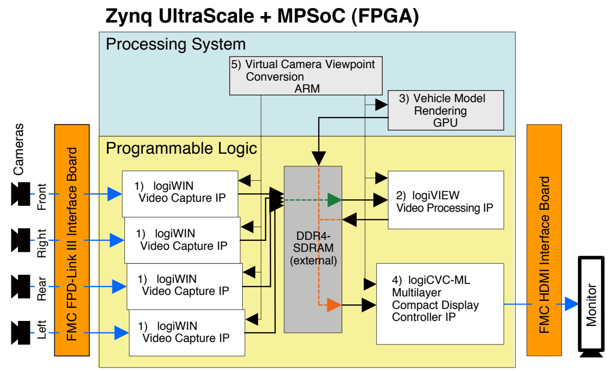

Figure 3. FPGA and Main Hardware Components

The feature of this platform is the use of the GPU to render the 3D vehicle model in order to suppress the consumption of hardware and software resources. Through 3D rendering, it is possible to generate high-resolution images without distortions or blind spots between cameras and the virtual viewpoint can be moved freely and quickly. Furthermore, repeated improvement in processing has enabled detailed, high-speed rendering of the 3D vehicle model.

The development of the platform succeeded due to OIDS's FPGA design technology that combined Xilinx's latest FPGA device and Xylon's image processing technology into a package.

Photo 4 shows the demonstration system using the platform developed for the flying camera system.

An aluminum frame was used to resemble a vehicle, and cameras were mounted in the four directions of the aluminum frame. A mouse was used in the demonstration to control the virtual camera viewpoint. It also featured a hands-free mode that works with a single click.

The user can change the virtual camera viewpoint at will by operating the mouse and is free to change the vehicle model and the surrounding image displayed in the output image. The response of the system easily allows the user to sense the high-speed processing.

*3) Zynq® UltraScale+TM MPSoC is a trademark or registered trademark of Xilinx Inc.
*4) ARM® is a trademark of ARM Ltd.

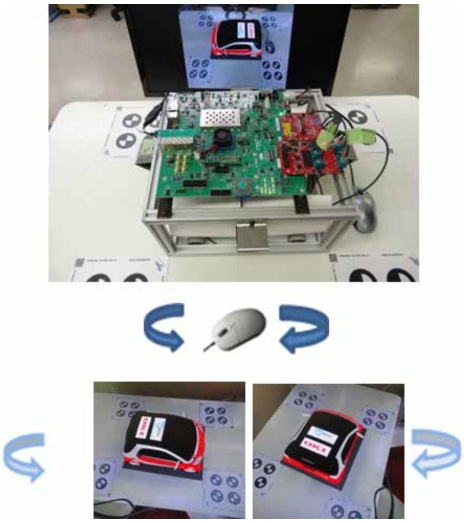
Photo 4. Flying Camera Demonstration System

Conclusion

This article introduced the flying camera system platform and demonstration system.

The co-creation partners' high-performance FPGA and IP were brought together with OIDS's strength in FPGA development to enable the virtual camera viewpoint of the conventional surround view system to be dynamically and freely changeable. The optimized FPGA resource has been configured with sufficient allowance for additional functions and circuit that may appear in future from various other technologies. Utilization of the platform will make it possible to add various other functions such as danger avoidance with vehicle surroundings monitoring and coordination with the next generation transportation system. Furthermore, a new system utilizing AI (Artificial Intelligence) will be developed for the detection and sensing field with the co-creation effort of Xilinx's Deep Learning Platform.

OIDS will continue joint development with co-creation partners mutually leveraging the areas of expertise and will expand the design service in the ADAS market. ◆◆

■ References

1) Oki Electric Industry Co., Ltd., press release "OKI Signs Agreement with Xylon for Exclusive Usage Rights of Advanced Driver Assistance Systems Technology," December 11, 2014 http://www.oki.com/en/press/2014/12/z14081e.html
2) Xilinx Inc., Zynq UltraScale+ MPSoC Datasheet: Overview https://www.xilinx.com/support/documentation/data_sheets/ds891-zynq-ultrascale-plus-overview.pdf

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TIPS 【Glossary】

FPGA (Field Programmable Gate Array)
A user programmable integrated circuit.

IP (Intellectual Property core)
Design information on reusable circuit components that constitute a semiconductor such as FPGA.

Zynq UltraScale+ MPSoC
Xilinx's FPGA device combining processor software programmability and FPGA hardware programmability on a single chip. Generically referred to as All Programmable SoC by Xilinx.

FMC (FPGA Mezzanine Card)
A standard for FPGA-mounted board based on an ANSI standard, which mainly performs I/O expansion.

FPD (Flat Panel Display)
Generic term for a device that displays images on a thin flat screen.

GPU (Graphics Processing Unit)
A processing unit dedicated to image processing. Performs rendering with an arithmetic unit specialized for real-time image processing.