Platform-Based Design Approach for Implementing Real-Time Image and Video Processing Applications

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Abstract*-Real-time image and video processing systems need to manage and process a large set of data in timely manner. Implementation of these systems requires satisfying various conflicting design requirements. Platform-based design has recently gained in importance which allows to explore the trade-offs between various design requirements for the implementation of real-time image and video processing algorithm and its systems. In this paper we present the exploration of platform-based design approach for implementing a real-time image and video processing system. We have used the platform-based design approach to design a real-time image and video acquisition module of a smart camera system.

***Keywords*-Platform-based design; Video acquisition; Real-time image and video processing; Virtex-5 FPGA.**

I. BACKROUND

Image and video processing systems are required to manage and process a large amount of data within real-time constraints [1-3]. As these systems have ever-increasing demand for higher performance and lower power; their design as embedded system continues to be a challenging problem. Further, the system design methodology places considerable conflicting constraints on the design of the system. Thus, there is a need for designing dedicated architecture and associated hardware modules to meet the expected performance requirement [3-5]. To achieve higher performance, we can realize the computation intensive complex algorithms in concurrently running hardware modules and rest is implemented on software which provides adequate flexibility [6-8]. To meet the several conflicting design requirements like power, performance, flexibility, design time and cost, the platform-based design has become an important choice for the implementation of these systems [9-10]. It also allows us to investigate various architectural trade-offs.

In platform-based design, the platform contains Field-Programmable Gate Array (FPGA), programmable clock generator, memory, microprocessor, common hardware peripherals, etc. along with some of the necessary interfacing ports and connectors to support the necessary protocols for the selected application space. Based on the application domain and performance requirements the suitable platform can be selected optimally. The available resources of the platform can be configured and used as per the design requirements.

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Thus, in a desired application space, we can run an extensive range of algorithms on the same platform by merely configuring the required peripherals and implementing some of the application-specific modules in custom hardware. The platform-based image and video processing systems can support a wide variety of applications including remote surveillance, motion analysis and traffic monitoring [10-13].

The rest of the paper is organized as follows: Section II describes the platform-based design approach. Section III gives a brief description of the image and video processing platforms, in general. In section IV we explain our design approach for the image and video processing applications with an example of image acquisition system using FPGA-based platform. Section V concludes this paper.

II. PLATFORM-BASED DESIGN APPROACH

In *application-driven architectural design* background, the term platform is defined as a collection of subsystems and required interfaces that form a common arrangement of functional units from which a system and its derivatives can be efficiently developed and shaped [10-12]. Platform is an abstraction of a group of varied micro-architectures which are programmable and occasionally, run-time configurable in nature. It offers a universal architectural component that can support a variety of applications as well as the future derivatives of a given application space.

Apart from having vital architectural building blocks it also satisfies the trade-off between a set of essential architectural constraints, such as, power, performance, area, design time, and cost. In Fig.1 such a platform-based design approach is depicted schematically. The selection of an appropriate platform depends upon the application space. Depending upon the application space, once a platform has been selected, the design procedure for the selected application begins by exploring the design space offered by that platform.

In the platform-based design, the software programmability comes from the availability of microprocessor and hardware programmability comes from the presence of reconfigurable blocks of FPGA. The combination of processor and run-time reconfigurable logic makes the platform provide the sufficient balance between the demands of application space and the architectural space. With embedded processor inside the FPGA, we can make trade-off between hardware and software to maximize the performance. To facilitate FPGA embedded processor design, Xilinx offers extensive libraries of IPs in the form of peripherals and controllers for their various platforms [14]. One such recent FPGA device available in the market is the Xilinx Vitex-5 FX family which offers hard processor embedded in FPGA fabric such as, *PowerPC 440* inside it [15].

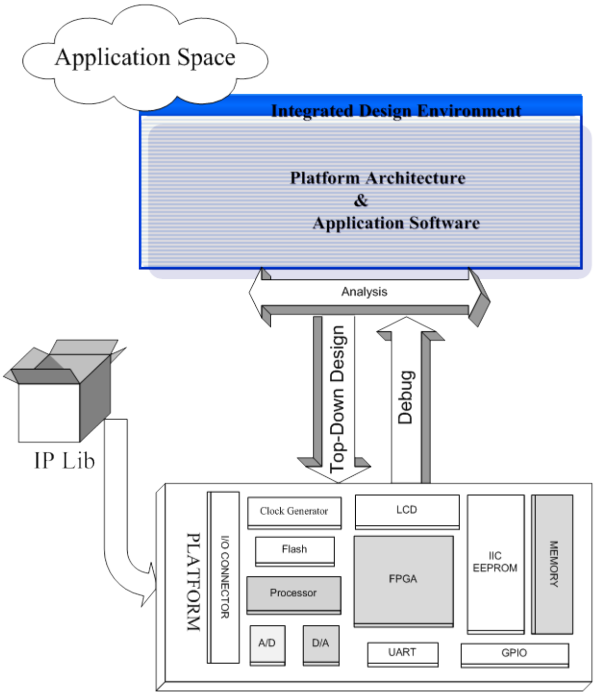

Fig.1. Platform-based design.

The platform-based design approach is an amalgamation based design approach which emphasizes systemic reuse for developing multipart products based upon the platform compatible hardware and software. It offers reduced developmental risks, NRE cost, and time-to-market [10-13]. Every element of the platform can be selected and used through the customization of an appropriate set of design parameters which controls its micro-architecture. The user may not be concerned about the design details of each and every components of the platform, standard bus and what is inside in the application programmer interface (API) as offered by the platform.

The platform-based design provides sufficient flexibility to support an application space for the selected design domain. In this design approach we can map our application into a conceptual representation which can include a range of micro-architectures that can be optimized for the various design needs. There are various integrated design environments available which offer complete support for the development of platform architecture and associated application software [16-17]. These platforms also offer debugging facility for the design analysis and its refinement. Thus, the platform-based design leverages the performance of most efficient derivative of an architecture and flexibility offered by the programmability of processor. The support of custom design hardware and reuse of IPs and other functional components make the platform-based design approach more favorable for architecture exploration of complex digital system [10-13].

III. Image and Video Processing Platforms

In the context of image and video processing platform, a general-purpose, multi-tasking, and reconfigurable platform has been presented in [18]. Based on the system level architecture of Xilinx Virtex-II FPGA, the prototype has been proposed and developed, which integrates embedded processor, memory control and interface technologies. The system includes different functional modules, such as edge detection, zoom-in and zoom-out functions, which provides the flexibility of using the system as a general video processing platform according to different application requirements. For real-time image acquisition and processing, an embedded platform has been presented by [19] which contain a Texas Instrument's TMS320C6416T digital signal processor and Altera's FPGA EP3C25F324. The digital image data has been, first, transferred into FPGA fabrics. After pre-processing, the data has been transferred into DSP6416 by the interface of FIFO in FPGA and DSP6416 EMIF. Further, the image data has been processed in DSP by real time algorithms. Bravo et al. [20] have used Xilinx Virtex-4 FX (XC4VFX12) FPGA based platform, which contains embedded PowerPC405 microprocessor. In their work they have presented architecture for image acquisition and processing using a CMOS sensor, which has been interfaced with FPGA platform for the smart camera.

IV. Platform for Image and Video Acquisition

In the proposed work the platform-based design approach has been used to design a real-time video acquisition module as shown in Fig 2.

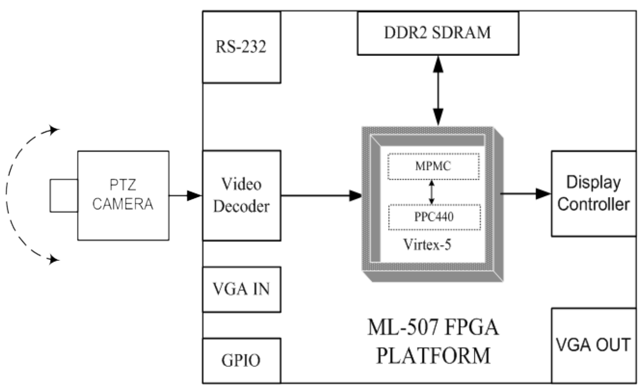

Fig. 2. Platform for image and video acquisition.

The design is based on Xilinx ML-507 platform having Virtex-5 FX device which has PowerPC440 embedded processor core. Along with the universal peripherals, the platform contains video decoder, display controller chip with necessary connectors which support wide range of image and video processing applications. Using the ML-507 platform peripherals and some of the customized logic in FPGA fabric, we have realized the image and video acquisition module. It facilitates the streaming of video from a Pan-tilt-Zoom (PTZ) camera to a VGA monitor through the FPGA logic and DDR2 memory in real-time. In this design, to interface DDR2 SDRAM memory with FPGA, we have used Multi-Port Memory Controller (MPMC) which has been available in the form of intellectual property (IP) module. The control registers of on-board peripherals are configured using the embedded PowerPC 440 processor with Inter-Integrated Circuit (IIC) bus controller's low-level device driver functions. The application software written in C language runs on top of a *standalone* software platform and uses the application programmer interface (API) provided by the software platform.

V. Conclusions

We have explored the platform-based design approach for designing real-time image and video processing application. Further, we have implemented a real-time image and video acquisition module using platform-based design approach. In the design, real-time video in RGB analog format has been captured from the PTZ camera. The captured video has been converted into the frames and buffered into DDR2 SDARM memory. The stored frames have been changed back into 640X480 VGA resolutions and displayed on the VGA monitor in real-time. The architecture uses Xilinx ML-507 FPGA board which has Virtex-5 FPGA. The total device utilization summary shows that, apart from the PowerPC 440 processor, the total FPGA resources consumed is around eighteen percent (18%). The left-over FPGA resources are sufficient for implementing most of the practical real-time video processing applications.

References

[1] N. Kehtarnavaz and M. Gamadia,"Real-time image and video processing:From research to reality," Morgan and Claypool Pub., 2006. doi:10.2200/S00021ED1V01Y200604IVM005.

[2] L. Guan, S. Y. Kung and J. Larsen, "Multimedia image and video processing," 2001, New York: CRC Press.

[3] A. Bovik, "Handbook of image and video processing," 2000, San Diego: Academic Press.

[4] D. D. Gajski, S. Abdi, A. Gerstlauer and G. Schirner, "Embedded system design modeling, synthesis and verification," 2010, New York: Springer Publication.

[5] D. D. Gajski, F.Vahid, S. Narayan and J. Gong, "Specification and design of embedded systems," 2007, New Delhi, India: Dorling Kindersley (India) Pvt. Ltd., Pearson Education.

[6] J. L. Hennessy and D. A. Patterson, "Computer architecture: A quantitative approach," 2nd ed., 1996, San Francisco, CA: Morgan Kaufmann Publishers Inc.

[7] D. A Patterson and J. L. Hennessy, "Computer organization and design:The hardware/software interface," 2010, San Francisco, California: Morgan Kaumann Publication.

[8] W. Wolf, "High performance embedded computing, architectures, applications and methodologies," 2007, San Francisco, California: Morgan Kaufmann Publishers.

[9] B. Bailey, G. Martin and T. Anderson, "Taxonomies for the development and verification of digital systems," 2005, New York: Springer Publication.

[10] L. P. Carloni, F. D. Bernardinis, C. Pinello, A. L. S. Vincentelli, and M. Sgroi, "Platform-based design for embedded systems," In R. Zurawski (Ed.), The Embedded Systems Handbook (pp. 1-26). 2005, Boca Raton, USA: CRC Press.

[11] F. Vahid and T. Givargis, "Platform tuning for embedded systems design," IEEE Transcations on Computer, 2001, 34 (2), 112-114. doi: 10.1109/2.901171.

[12] A. S. Vincentelli and G. Martin, "Platform based design and software design methodology for embedded systems," IEEE Design and Test of computers, 2001, 18(6), 23-33.

[13] M. Burton and A. Morawiec, "Platform based design at the electronic system level," 2006, The Netherlands: Springer Publication.

[14] FPGA, CPLD and EPP solutions from Xilinx Incorporation. http://www.xilinx.com.

[15] Virtex-5 FXT FPGAs. http://www.xilinx.com/products/virtex5/fxt.htm.

[16] B. Bailey and G. Martin, "ESL models and their application," 2010, New York: Springer Publication.

[17] D. Densmore, R. Passerone and A. L. S. Vincentelli, "A platform-based taxonomy for ESL design," Co-published by the IEEE CS and the IEEE CASS, 2006, pp. 359-374.

[18] J. Li, H. He, H. Man and S. Desai, "A General-Purpose FPGA-Based Reconfigurable Platform for Video and Image Processing," Advances in Neural Networks, 2009, Vol. 5553/2009, 299-309, doi: 10.1007/978-3-642-01513-7_32.

[19] Y. Lei, Z. Gang, R. S. Heon, L. C. Young, L. S. Ryong, Bae and Ki-Man, "The Platform of Image Acquisition and Processing System Based on DSP and FPGA," International Conference on Smart Manufacturing Application, 2008, April. 9-11, in KINTEX, Gyeonggi-do, Korea.

[20] I. Bravo, J. Balinas, A. Gardel, J. L. Lazaro, F. Espinosa and J. Garcia, "Efficient smart CMOS camera based on FPGAs oriented to embedded image processing," 2011, *Sensors*, 11(3), 2282-2303. doi: 10.3390/s110302282.