

Image Fusion Using FPGA

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Abstract—Image fusion is the combining process which fuses relevant information from two or more images to form a single image. The image results will be more informative than any of the input images. Image fusion techniques can be able to improve the quality of images and increase the application of the data. Image fusion is much required as because, multi-sensor data fusion has become a discipline which demands more general formal solutions to a number of application cases. Several situations in processing an image require both high spatial and high spectral information in a single image that is important in remote sensing and medical imaging. Moreover, the instruments also are not capable of providing such information either by its design or because of observational constraints. One possible solution for this is data fusion. In image fusion, FPGA is often used as implementation platforms for real-time image processing applications. Field Programmable Gate Arrays are popularly known as FPGAs. These are semiconductor devices that are based on a matrix of configurable logic blocks (CLBs) connected via programmable interconnect. FPGAs can be reprogrammed to the desired application or functionality requirements after processing. An FPGA is programmed by connecting a large number of gates together to form multipliers, adders, registers. FPGA dedicates logic for receiving data so can maintain high rates of input and output data images. FPGA does many high sampling rate applications easily. It is mainly used for giving high performance HD images.

Keywords—FPGA, Image fusion, Medical imaging.

I. INTRODUCTION

Image fusion means the process of fusing two images to form a single image which provides clear information content about the given images. With advancements in technology, it is now possible to obtain information from multi-source images to produce a high quality fused image with spatial and spectral information. Image Fusion is a mechanism that is mainly used to improve the quality of information from a set of images that is being fused. Important applications of the fusion of images comprise medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Use of the Simple primitive technique will not recover good fused image with regard to the performance of the parameters like Peak Signal to Noise Ratio (PSNR), Normalized correlation (NC), and Mean square error (MSE). In recent years, Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA), Morphological processing and Combination of DWT with PCA and Morphological techniques have been a popular fusion of image. These methods are shown to execute much better than simple averaging, maximum, minimum.

One alternative is to utilize a Field Programmable Gate Array (FPGA). Continual growth in the size and functionality of FPGAs over recent years has resulted in an increasing interest in their use as execution platforms for image processing applications, particularly real-time video processing and providing HD images. An FPGA consists of logical blocks in a matrix form which is connected by a switching network. Both the logic blocks and the switching network are reprogrammable permitting application specific hardware to be constructed, while at the same time maintaining the ability to change the functionality of the system with ease. FPGAs offer a compromise between the flexibility of general purpose processors and the hardware-based speed of ASICs. Performance gains are obtained by sidestepping the fetch-decode-execute overhead of general purpose processors and by exploiting the inherent parallelism of digital hardware. FPGAs are often used as implementation platforms in all environments for real-time image processing applications. A Field Programmable Gate Array (FPGA) is a programmable device in which the final logic structure can be directly configured by the end user. An FPGA consists of an array of uncommitted elements that can be programmed or interconnected according to a user's specification in a virtually limitless number of ways.

II. ROLE OF FPGA

An FPGA is commonly said to be an independent "sea of gates". FPGAs are semiconductor devices that are programmed by connecting the gates together to form multipliers, registers, adders. Using the Xilinx core generator this process can be done at a block diagram level. Many of the logic blocks in FPGA can be at a very higher level ranging from a single gate to an FIR (Finite Impulse Response) or FFT (Fast Fourier

Transform). Performance is restricted by the number of gates they have and the clock rate. FPGAs consist of some following characteristics that are more appealing for video and image processing architectures, such as:

- The High performance of HD image processing can be implemented in a single FPGA.
- Flexibility in FPGAs provides the ability to upgrade architectures quickly to meet evolving requirements.
- Scalability allows the use of FPGAs in low cost and high-performance systems.
- Video and Image Processing solution includes optimized DSP design flows, Image processing suite and third-party video compression IP, and video reference designs for providing better quality images.

In Addition, Adaptive filters are used to remove noise without blurring the structures in the image. These adaptive filters are said to be the heart of Active Vibrato Control System which are traditionally implemented using DSP processors due to their ability to perform fast floating-point arithmetic in images. General purpose DSPs are modified with efficiency for common signal processing operations. DSP systems based on software's are flexible, but due to sequential nature of microprocessors, suffer from insufficient processing capability. These are the fastest method to get an algorithm running because this offers a comprehensive development environment, with tools for code analysis, debugging and rapid prototyping. On the other hand, FPGAs are Reconfigurable hardware devices wherein it is possible to change the topology of electronic circuits at runtime. FPGAs incorporate arrays of dedicated multipliers, embedded memory and high-speed I/O that make them obsolete for DSP applications. Also in recent times due to its growing die size as well as incorporating the embedded DSP block, the FPGA devices have become a serious role in the signal processing field. It is not yet possible to use floating-point arithmetic in modern FPGAs, but it is sufficient to use fixed-point arithmetic and still, it can achieve tap-weight convergence for adaptive filters.

In transversal adaptive filters, each tap, as well as components for updating each filter coefficient, requires a multiplier and an adder. By an instance, the use of the required number of multipliers and an adder, the performance of FPGA based filter can be increased significantly compared to DSP processors. FPGAs allow a great deal of parallelism to be incorporated. Also, the new generation of FPGAs from Xilinx has embedded DSP slices within the device, which have dedicated circuitry to perform additions and multiplications, which are fundamental for any DSP applications.

III. THE BENEFITS OF FPGA

The salient features of FPGAs that construct them superior in speed, over conventional general-purpose hardware like Pentiums is their greater I/O bandwidth to local memory, pipelining, parallelism and availability of optimizing compiler. Complex tasks that are performed using multiple image operators, run much faster on FPGAs than on Pentiums. There are several reasons for such large speed up which FPGA devices have over PCs. In comparison to an FPGA device, Pentium hardware runs at memory speed, not at cache speed. So, even running at the much higher clock frequency and having the facility of cache memory, it responds much slower than a comparable FPGA. The frequency of operation in hardware such as Pentium can be increased up to a certain extent to increase the performance or the required data rate to process the image data, but increasing the frequency above certain limits causes system level and board level issues that become congestion in the design. However, the contrast in speeds also depends on the particular application involved. In specific, the complex image processing applications does enough image processing per pixel to be computation bounded, rather than I/O bound. Here, FPGAs dramatically exceed Pentiums by factors of up to 800. Simpler image handling operators tend to be I/O bounded. In these cases, FPGAs still go beyond Pentiums because of their greater I/O capabilities, but by smaller margins.

IV. THE CONSTRAINTS OF FPGA

- At present, there are many expense in FPGA design. This includes data transfer times which is the time required to upload or download the data, from or to a reconfigurable processor to or from a host; time for reconfiguration. FPGA is known to be an Efficient and Promising Platform for Real-time Image Processing Application.
- FPGAs are an excellent choice only for those algorithms which don't use floating -point mathematics or complex mathematics. Division, direct multiplication is very complex and expensive on FPGA. Hence, the designers have to redevelop their algorithms and avoid complex mathematics.
- Current FPGAs cannot be reconstruct quickly as the process of modifying or combining FPGA circuits is also laborious.
- The size of memory that can be implemented by using standard logic cells on an FPGA is limited, as implementing memory is an inefficient use of FPGA resources.

- Routines, where complex tasks cannot be burst down into simpler tasks, must perform a more serial method of processing, whi The performance needs for near real-time analysis require system platforms thatch is not entirely efficient with FPGAs.
- Hardware offers much greater speed than a software implementation, although it comes with a price of increased development time inherent in creating a hardware design.

V. APPLIANCE OF FPGA

There are many applications in implementing FPGA for its simplicity and effectiveness. Various applications such as:

- Medical Imaging
- Remote Sensing
- Non-destructive Evaluation
- Textiles
- Forensic studies
- Material Science
- Military
- Film industry
- Document processing
- Graphic arts
- Printing industry

VI. MEDICAL IMAGING

Medical imaging is one such popular technique utilised for the process of creating images of the human body for clinical purposes or medical science. Although imaging of removed organs and tissues can be performed for medical justifications. Medical imaging is said to be a part of biological imaging since it is widely required for human need. And it integrates radiology, nuclear medicine, investigative radiological sciences, endoscopy, thermography, medical photography, and microscopy.

Several factors are considered for the efficient development of flexible medical imaging equipment:

- Imaging algorithms are developed for better quality images which require high-level intuitive modelling tools for continual improvements in digital signal processing (DSP).
- The performance needs for adjacent real-time analysis require system platforms that scale with both software (CPUs) and hardware (configurable logic). These processing platforms must meet various performance price points and be competent of bridging the fusion of imaging modalities.
- System architects and design engineers require to quickly partition and debug algorithms on these platforms, using the latest tools and intellectual property (IP) libraries to speed their deployment and improve profitability.

VII. MEDICAL IMAGE EQUIPMENT

A. RADIOGRAPHIC IMAGING

The conversion from Computed radiography (CR) to Digital radiography (DR) is well underway which results in digital X-ray images. The benefits of digital flat-panel detectors allow images to be processed within seconds, thus increasing productivity, while eliminating the handling of cassettes and associated chemicals for film processing.

In addition, portable DR systems are increasing in acceptance. Many of these smaller profile systems offer tether less flat-panel detectors using wireless connectivity removing the cables that are failure points and sources of workplace injuries. FPGAs can support the changing protocol stacks from wired to wireless and lead the power sequencing and monitoring in these digital detectors.

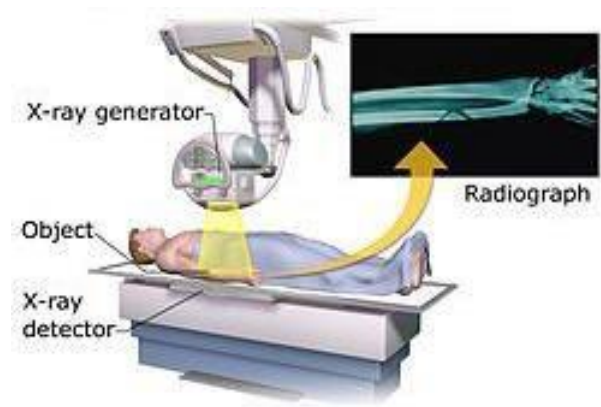


Fig. 1. Radiography

B. MOLECULAR IMAGING

X-ray or CT scans provide images of anatomical structures; molecular imaging is well suited for images of cellular functions and metabolic processes. Two commonly used modalities are Single-photon-emission computed tomography (SPECT) and PET platforms. Advances in PET include increased detector counts; expanded detector pairing areas, shortly coincidence windows, time-of-flight technology, and more advanced algorithmic modelling. Significant increases in raw data require faster processing abilities and pre-processing decisions earlier along the data path. In many systems, FPGAs are used in the aggregation stages of the electrical signals from the photo sensors and data converters. The intrinsic programmable nature of FPGAs allows newer designs to increase pre-processing decisions along the data path, thus reducing the amount of data delivered to the reconstruction stage.

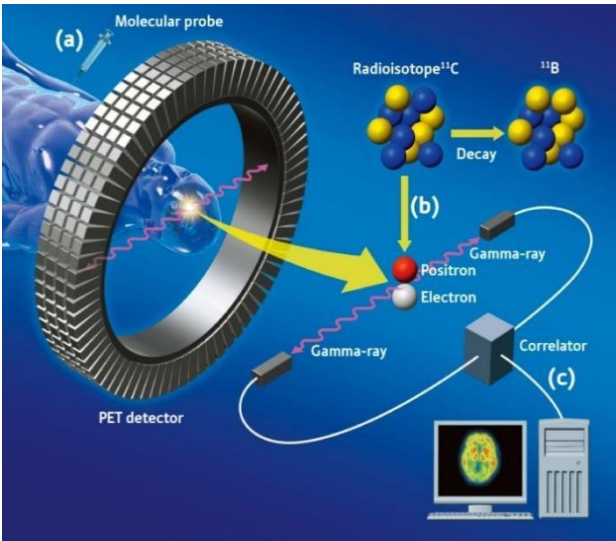


Fig. 2. Molecular imaging by PET

C. MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging (MRI) reconstruction creates images cross-sectional images of the human body. First 2D slice reconstructions are thrived using Fast Fourier Transform (FFT) functions of the frequency domain data. Sharpening and spatial de-blurring techniques are employed, reducing noise while sharpening the image. Many of these are building blocks within the VIP and DSP libraries within easy reach for implementation in FPGAs. From this, 3D volumes reconstructions are generated from interpolation techniques.

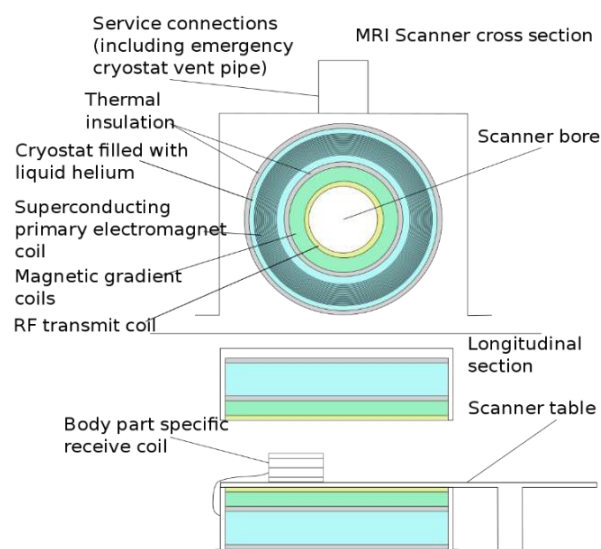


Fig. 3. MRI scanner

D. VIDEO IMAGING

In video imaging, the one such standard equipment in field for many years has been radiopaque contrast angiography from X-ray images of blood vessels, which used by salt-based contrast agents. At present, CT angiography, time-of-flight/phase contrast MR angiography, and duplex/intravascular ultra-sonography are more commonly used. These techniques in video imaging involve simultaneous acquisition and registration of optic-acoustic and ultrasound images, segmentation of vascular and skeletal images. And it is implemented in diagnosing lung disorders in which the correlation based enhancement filters are used to reduce false positives in human body. For detection of cancer in earlier days, the Bio Scan System has been implemented. The Bio-Scan System is based on a sensor called the Quantum Well Infrared Photodetector (QWIP) that is sensitive to temperature changes of human body. The digital sensor detects the infrared energy emitted from the human body affected by the cancer disease, to display the minute differences associated with increased blood flow in video imaging. A classic development of an image fusion method is a programmable systolic array implemented with a general-purpose workstation and a special purpose hardware engine built from FPGAs device. This special purpose engine from FPGA can accelerate the core algorithm nearly 1,000 times faster than the rate achieved by a state-of-the-art workstation. Additionally, cardiac motion estimation constitutes aid in quantifying the elasticity and contractibility of the heart muscle. Localised areas exhibiting abnormal movements are indicative of schematic heart regions, where insufficient circulation exists. One such developing algorithm in FPGA includes flexibility in the quantitative evaluation from a series of ultrasound images that detects the video signals using spatial-temporal registration techniques to gain the deformation field with respect to reference frame in each fused images in video.

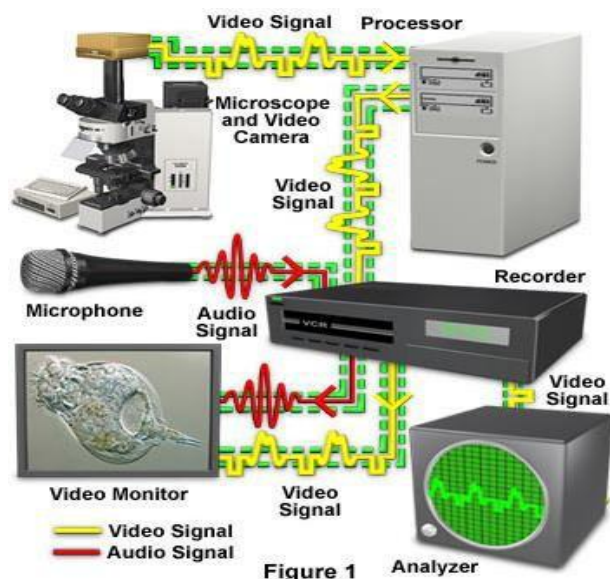


Fig. 4. Video Microscopy Schematic Diagram

VIII. CONCLUSION

FPGA devices are directing major efforts to address DSP (Digital signal processing) applications for medical imaging. The FPGA solutions will increasingly provide the processing power to new medical imaging applications required to handle challenges such as ultra-high signal processing performance, very-high memory bandwidth, and increased interconnectivity between processing elements. Now with the emerging architecture, FPGAs are the greatest support for video and image processing applications, such as broadcast infrastructure, medical imaging, HD video conferencing, video surveillance, and military imaging. Video and image processing solutions for FPGAs include optimized development tools and kits, reference designs, video compression IP, and interface and system IP, and also video and image processing IP suite. These solutions can improve cost, performance, and productivity for many video and imaging applications in future. For the past years, with a multibillion-dollar market increase in FPGA speeds and capacities have followed or exceeded Moore's law. This paper clearly demonstrates the outstanding features of FPGAs which shows very promising choice for the researchers in the field.

FPGAs device consists of many logic blocks used for developing real-time image processing applications and their structure holds both spatial and temporal parallelism. Such parallelization is subject to the processing mode and hardware restrictions of the system. FPGA devices use high-level languages and compilers to hide the constraints and parallelism is extracted at the same time from the code does not always produce an efficient mapping to hardware. For a clear image manual mapping is done that removes the application software restriction, and moreover the designer deals more closely with timing, resource, and bandwidth constraint which complicate the mapping process. Timing or processing limitation can be met using pipelining. All these processes provide quality in image fusion. In this paper some general techniques of medical imaging using FPGA concern for evaluating complex expressions to help deal with resource constraints by reducing logic block usage. The mapping of three distinct types of operations was discussed in relation to the hardware constraints. Image fusion procedure combines original information from various images. This gives the resultant image as an original image. In this field process, FPGA provides better innovation for image fusion methods. In future, FPGA overcomes with new techniques to provide creative images.

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