Fpgas Enhance Medical Imaging Allowing More Efficient Diagnosing And Precise Surgical Procedures

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***Abstract*—** In this paper, a technique for improving the processing speed of medical imaging algorithms and the image resolution of the images produced by imaging techniques is proposed. Field programmable gate arrays (FPGAs) can implement certain computational tasks, to get the highest performance. The purpose of this research paper is to discuss how this may be done to maximize the benefits of medical imaging in diagnostic and surgical procedures.

Keywords-component; field programmable gate arrays; FPGAs; medical imaging; MRI; processing speed; higher-resolution; precise surgical procedures; efficient diagnosing

I. Introduction

According to Merriam-Webster's dictionary, medical imaging can be defined as the action or process of producing an image especially of part of the body by radiographic techniques. There are numerous different applications for medical imaging techniques such as; during surgical procedures to assist surgeons to see details the human eye cannot, for the disease diagnostics and for conducting research and gathering medical data.

For example, according to Owens [1], clinicians use magnetic resonance (MRI), to show the loss of brain cells associated with Alzheimer disease. The scans provide useful information which showed that the brain cells begin to change years before clinical symptoms appear.

As mentioned above, another application for medical imaging technology is during surgery. A suspicious lump of cancer for example, looks exactly like the rest of the breast tissue to the human eye. However, precision medical imaging - whether its magnetic resonance imaging (MRI) or computed tomography (CT) – can tell the difference thus guiding surgeons and radiologists. In 2003, the first radiation machine with CT scanner was designed [1]. The equipment allows radiologists to trace the outline of the tumor before each dose of radiation. The resulting confidence being that they can avoid healthy tissue. This has allowed doctors to increase dose of radiation. Image guidance is particularly valuable for cancer treatment because it addresses the primary challenge: how to remove every last bit of tumor while damaging as little healthy cells as possible.

In addition, researchers are working to adjust these maps during surgery, so they update more quickly in real-time, moving and shifting along with the patient. This is known as real-time imaging. The images produced guide surgeons and radiologists past healthy tissue to the diseased cells. The challenge is to take the surgical scan as quickly as possible and line it up accurately with pre-surgical images, says Gavin Winston, a neurologist at University College London [1].

In the early 1990s, Jolesz pioneered the use of MRI in operations, taking scans during brain surgery for the first time. When this was successful, it became clear that the best way to guide treatment and surgery was to combine as many forms of medical imaging techniques as feasible. Imaging during surgery can address the problem of over treating early-stage tumors, such as those found during routine lung CT scans on smokers. But nowhere is accurate targeting more essential than in the brain, where neurons that control key functions may snake past a tumor. What's more, a tumor can reorganize the brain's function, shifting neuronal connections. To address this, surgeons are developing ways to glean information from MRI scan such as functional MRI [1].

Functional MRI highlights the parts of the brain that receive the most blood when patients perform a task, revealing which regions may be involved in certain functions. Researchers can turn this data into maps that paint brain tracts different colors according to their direction, identifying information highways once invisible to surgeons. Using these scans to inform surgery has dramatically improved patients' outcomes, says Christopher Nimsky, a neurosurgeon at the University of Marburg in Germany. "Ten or twenty years ago, it was accepted that there was a 10-15% chance of neurological deficits after surgery. Now thanks to medical imaging during surgery there is only a 2-3% chance, even in complicated cases."

The functional maps which doctors have been using routinely over the last eight years (since 2008), help them to decide which patients would be too impaired by surgery to make it worthwhile. It has also given doctors the confidence to pursue more aggressive surgery in certain cases.

From the discussion thus far, one can deuce that characteristics of medical imaging technologies such as processing speed and image resolution if improved would vastly revolutionize the how effectively medical imaging techniques are applied in the above mentioned applications and others. This can mean more accurate diagnosing, more precise and efficient surgical procedures and more useful data gathered for research purposes.In this research paper, we explore how field programmable gate arrays (FPGAs) can be implemented into existing medical imaging techniques and approaches to improve the processing speed and image resolution.

The structure of this research paper is as follows. Firstly, a brief description of each of the six (6) most popular medical imaging techniques is given, followed by a comprehensive idea of the existing approaches to medical imaging, meaning, how the techniques are typically integrated with each other for improved performance in practical applications. The drawbacks of the approaches are then briefly stated. Following this, we introduce the background behind FPGAs, which includes a brief discussion on their advantages and limitations. Existing research on how FPGAs have addressed the drawbacks of medical imaging approaches thus far is then stated. Lastly, the prosed solution to improving the processing speed and image resolution of medical imaging techniques is proposed along with its possible benefits.

II. Medical Imaging Techniques And Approache

A. Different *Types of Medical Imaging Techniques*

According to Owens [4], there are six (6) different types of Medical Imaging techniques used, namely:

1. Magnetic resonance imaging (MRI) which is used to examine soft tissue such as joint ligaments, and the brain.

2. Computed tomography (CT) which uses computers to process X-rays and crate images of slices of the body. These cross-sectional images can then be assembled to detect tumors, bone damage and potential hemorrhages.

3. Ultrasound uses sound pressure waves with a frequency beyond human hearing which can be used to image soft tissues in the body, most commonly a developing fetus.

4. The X-Ray is the oldest and still the most common form of medical imaging which is used to examine the lungs and hard tissues such as bone.

5. Positron emission tomography (PET) detects the gamma rays produced by a radioactive tracer introduced into the body that is specific to the tissue of interest. It is used extensively in cancer diagnostics to locate tumors.

6. fMRI is a research technique that is beginning to find clinical uses, function magnetic resonance imaging measures brain activity by detecting associated changes in blood flow.

B. Existing Approaches to Medical Imaging

Medical technologists are working on several fronts to improve the quantity and quality of information gathered in a single scan. That often means combining modalities in complementary ways — for example, adding structural information from computed tomography to the functional data from positron emission tomography.

In 1991, David Townsend, a physicist then at the University of Geneva in Switzerland, built a low-cost positron emission tomography (PET) scanner. The design left some spaces in the instrument's structure, and Townsend wondered whether he could fill them, and improve the machine, by squeezing a second scanning technology into the gaps. A doctor friend told him that surgeons were more familiar with the anatomical information provided by computed tomography (CT), so he added that, and the PET–CT scanner was born.

At first, many in the medical establishment were sceptical about the instrument's potential.But what was unfamiliar 15 years ago has since become the norm. These days, “any sensible person would not use PET alone,” says Vannier, adding that the PET–CT scanner has “vastly improved doctors' ability to identify the stage of a lymphoma, allowing more nuanced treatment decisions.” Simon Cherry, a biomedical engineer at the University of California, Davis, agrees. “It's almost impossible to buy a PET scanner without a CT scanner attached to it now,” he says.

That success has spurred other efforts to combine imaging modalities. None of the many ways of looking inside the human body is perfect, but merging the strengths of two or more technologies may allow physicians to see details they have never seen before and improve the detection, diagnosis and treatment of ailments ranging from cancer to heart disease or Parkinson's disease.

Imaging techniques mainly show either structural information — the physical shape of an organ or a tumour — or functional information, such as which molecules are present or what metabolic activity is occurring. But no single technique is optimal for both.For example, X-ray tomography can spot tiny breast tumours but has trouble telling which are benign and which are malignant. This lack of functional information leads to a lot of false positives, followed by unnecessary surgery, says Lihong Wang, a biomedical engineer at Washington University in St Louis. “If you can tell the function, you can get more information,” Wang explains. “The end result is higher accuracy.”

The structural information provided by ultrasound can also be combined with the molecular information available through confocal microscopy, an optical technique that provides high-resolution images, allowing scientists to identify molecules when a fluorescent tag latches onto them. “They're perfectly complementary techniques,” says Christopher Contag, a microbiologist at Stanford University's Molecular Biophotonics and Imaging Laboratory. He suggests going even further in combining techniques: adding a third, such as photoacoustics, would make the images even richer.

Contag's approach could provide enough information for doctors to perform histopathology inside a living patient, instead of on a piece of excised tissue in a lab. This would not only reduce the need for biopsies, but could also improve the accuracy of the diagnosis. Tissue that has been removed and stuck to a microscope slide might be dried out, reshaped or otherwise changed by the process. Leaving it in place avoids those problems.

Another approach (Multispectral MRI) to making images richer is to mix together not data from different technologies, but different results from the same technology. Multispectral magnetic resonance imaging (MRI) is a case in point. Conventional MRI uses radio-frequency pulses and changes in the magnetic field to create an image. Each specific sequence of pulses provides its own type of image, or contrast, making different types of tissue easier to see.A group led by neuroscientist Suzanne Corkin of the Massachusetts Institute of Technology combined four of these contrasts to look for early signs of the brain damage caused by Parkinson's disease.

Two of the contrasts provided by different pulse sequences show the boundaries of the substantia nigra, but individually each is a bit fuzzy, says David Ziegler, a neurologist at the University of California, San Francisco, who worked with Corkin on the MIT project. A third contrast shows white matter appearing very bright, but cannot distinguish it from cerebrospinal fluid, whereas a fourth makes the fluid look black, so putting those two contrasts together makes it clear which is which.

The trick to multispectral MRI is to take all the scans in the same session. Any MRI image has some distortions, which can be corrected for. But with multiple scans, the images must be aligned correctly for that to work; scans from separate sessions would be hard to line up.

The latest combined technology is the PET–MRI scanner, designed by Cherry and only just coming onto the market. Using PET, which is useful for finding biomarkers, adds functional information to the MRI image. The combination could improve imaging of the brain and of the soft tissue in the pelvic area, helping to identify such diseases as bladder or brain cancer. Cherry says the combination provides the best of both worlds: "PET is the most sensitive technology out there. MRI is the highest-contrast technology."

Imaging that combines structural and functional information might not only increase early detection, but also guide doctors about what to treat and what to leave alone. "The imaging," Vannier says, "will provide the tool that in clinical practice will allow you to confidently make the decision."

C. The Drawbacks of Medical Imaging Techniques

The following list highlights the most common drawbacks that are faced when employing medical imaging techniques.

1. Some imaging procedures can expose patients to high levels of radiation, so the number and timing of scans must be carefully controlled over there lifetime as high doses of radiation is known to destroy not only the unhealthy cells, but healthy cells also.

2. Medical imaging systems are high processing systems. They require lots of computational power to process data from scans to form the images. As such the speed at which it is processed and the image resolution is often compromised.

D. Summary

Therefore, while, yes, existing approaches aim to address these drawbacks by fusing diagnostic image modalities as seen in part B of this section, another factor that can address these drawbacks and further improve imaging techniques is computational performance. Advanced algorithms, like those used after medical imaging modalities are combined, require scalable system platforms with significant increases in image processing performance, yet in smaller, more accessible, portable equipment. Improving the computational performance used to process the raw data from the imaging approaches can thus further enhanced how effective these approaches would be at diagnosing patients and how precise images produced would be during surgical procedures.

III. Field Programmable Gate Arrays, And How They Have Been Found To Address Medical Imaging Drawbacks Thus Far

Firstly this discussion begins with a brief description on what are FPGAs along with their related advantages and limitations. Following this, how FPGAs have been found to address medical imaging drawbacks thus far is explored.

A. What are field-programmable gate arrays (FPGAs)?

Field-programmable gate arrays (FPGAs) are integrated circuits, which constitute an array of logic blocks (cells) placed in an infrastructure of interconnections which can be programmed. FPGAs are highly versatile devices that offer the designer a wide range of design choices and options.

B. Advantages of using FPGAs

FPGAs enable engineers to mitigate the effects entailed by the well-known tradeoff in computing between cost and performance.

For instance, when one sets about implementing a certain computational task, to get the highest performance (speed), one much construct specialized hardware. This possibility exists in the form of application-specific integrated circuits (ASICs); however, the price per application as well as the turnaround time (from design to actual operation) are both quite prohibitive.

Thus, the computing industry has opted for general purpose computing, which trades maximum speed for much lower design and implementation costs. A general purpose processor can be easily and quickly instructed to change its task. This ability is made possible since such a processor is programmable; nonetheless, programming (and reprogramming) does not change the processor's hardware. An FPGA is programmable at the hardware level, thus combining the advantages of both general-purpose processors and specialized circuits.

C. Limitations to using FPGAs

However in order for the FPGA to achieve all its functionality, it necessitates a suite of tools in order to design a system such as Xilinx.

However this can problem can easily be addressed by hiring individuals trained in the use of Xilinx or other similar tools to design and implement the system.

D. How field programmable gate arrays have been found to improve medical imaging drawbacks thus far.

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From our discussion on medical imaging drawbacks, in part C of the previous section, there are two main drawbacks to medical imaging. One drawback can directly affect the patient's health and would not be the focus of this paper. The other drawback looks at the more technical limitation to medical imaging systems, i.e. that computational power is directly linked to processing speed and image resolution, thus how well the medical technology performs in different applications. This drawback can affect how well a patient is diagnosed or how smoothly a surgical procedure is performed. Thus it is important to continuously make improvements here to enhance the performance of imaging systems.

In previous work [4], for a CT scanner back projection algorithm, an FPGA platform and high-level tool called Impulse C was used to speed up a statistical line of reaction (LOR) estimation for high-resolution Positron Emission Tomography (PET) scanner. The estimation algorithm provided a significant improvement over conventional methods, but the execution time was too long for practical clinic applications. Impulse C allowed the researchers to rapidly map a C program into a platform with a host processor and FPGA coprocessor. The results showed that FPGA implementation could obtain an 82x speed up over conventionally optimized software methods.

IV. Proposed Method Of Using Fpga In Improving The Performance Of Medical Imaging Systems

From part D, section III of this paper, we have seen how FPGAs have improved how fast algorithms used in medical imaging approaches can be processed. Particularly, a 82x speed up was observed over conventional software optimization methods. Thus we notice the direct impact FPGAs can have on the performance.

Another important point that was considered, is that in considering what hardware configuration to use for real-time digital signal processing, there are a number of important technical specifications, particularly the time required to perform a fast Fourier Transform (FFT) because so much of image reconstruction is based on the Fourier transformation. In addition, there are many other mathematical interest beyond FFTs. The point here being that, if we improve the processing speed of these mathematical processes we can directly have a positive impact on how fast digital images are processed and how quickly they are reconstructed.

We have noticed thus far that medical imaging tasks require high-performance signal processing to convert sensor data into imagery to help with medical diagnostics and surgical procedures. FPGAs are a compelling platform for these systems, since they can perform heavily pipelined operations customized to the exact needs of a given computation.

Thus, it would seem very relevant to design an FPGA architecture specifically which will leverage high speed digital processing (DSP). Such an FPGA when implemented to process complex medical imaging algorithms could improve the speed 82x and more.

V. Conclusion

In conclusion, the integration of FPGAs into existing medical images approaches can provide several benefits to patients, medical personnel, surgeons and radiologist. These benefits in (1) that medical personnel would be able to make more accurate and quick diagnostics as the images produced are timely and sharper, (2) surgeons could perform more precise surgical procedures using the clear and quickly produced images from medical imaging technologies, (3) radiologists can better direct treatment to unhealthy cells only and avoid damaging healthy cells.

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