Status and Hardware Requirements of 3D Imaging Systems

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ABSTRACT

The real world is composed of objects in three dimensions. With the advancement of High-Definition Television it is logical that the next step to increase the sense of reality will be the reproduction of depth, thus yielding three-dimensional (3D) viewing of images. 3D Imaging is a very complex issue with many still unanswered questions. Implementation of the various complex 3D algorithms in hardware is a critical priority.

This paper will review the present status of 3D Imaging and then discuss our work on the hardware requirements of a system used to process 3D image data in advanced imaging systems and applications. In particular we will discuss how Texas Instruments' world class DSPs can be used to meet the complex algorithmic codec challenge. Also, the paper will state the data rates that the system will need to handle ranging from low to high-resolution images and certain possible transmission media will be acknowledged.

1. INTRODUCTION

There are assorted issues that are considered in reviewing the present status of three-dimensional (3-D) imaging. The issues considered have to include the driving force behind the present research on 3-D imaging and the groups that are involved in the particular research. Human factors are also dominating in the field of 3-D imaging as Motoki et al [10] have previously reported on their work with 3-DTV. In 1958 the CCIR established a program to look into 3-DTV and the issues raised by the program study still hinder 3-DTV broadcasting today. CCIR program study agreed to embark on the following studies among others:

(1) Investigations on developing 3-D displays that would not require the use of special glasses,
(2) Investigate on possible bandwidth reduction methods for 3-DTV that will be compatible with present systems, and
(3) Research on designs of TV receivers that can directly reproduce 3D images [10].

These points are as important today as they were 42 years ago. Presently, psychologists mainly based in the United Kingdom are demonstrating how people prefer 3-D images to the present 2-D pictures that they normally see on regular TV [6]. The whole motivation is based on the fact that people recognize that it is better to realize the real world information as it stands rather than in two dimensions as the television has always portrayed. It is acknowledged that quality of the pictures alone does not satisfy the audience, hence the preference of going beyond HDTV. Just like it was pointed out by the CCIR in 1958, the present day developments of

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3-D imaging systems still depend mainly on the displays for success. It is in this light that many people involved in 3-D imaging have concentrated most of their work on 3-D displays, whilst a considerable number has been working on human factors.

This paper will review the present status of 3D Imaging and then discuss our work on the hardware requirements of a system used to process 3D image data in advanced imaging systems and applications. The next section will describe the current state of 3D Imaging. Section 3 will describe the architecture of a 3D imaging system and possible hardware implementations of the coding system using Texas Instruments' DSPs and Programmable Logic Devices. The final section is a discussion of the authors' views of the future of 3D imaging systems as well as plans for future research.

2. Status of 3D Imaging

Researchers that have worked on human factors are concentrating on psychological effects the 3-D systems have on people, particularly the people's sensations of presence when viewing 3-D images [6]. Focus groups used in the United Kingdom by the psychologists, Freeman and Avons reported feelings of being part of whatever was being displayed on 3-DTV screens. The people that were tested pointed factors such as realism, naturalness and interest as part of the results of their sensations of presence. The work performed by psychologists continues to support the development of 3-D systems. The Heinrich-Hertz Institute in Germany also did a study that showed that 3-D images are preferable to 2-D images [10].

In order to achieve the task of the realization of 3D-TV, different corporations and institutions around the world have contributed a lot of resources towards the development of 3-D imaging systems. In Japan, NHK, the innovators of HD-TV (Hi-Vision) have opened ways for new possibilities because of their excellent work with HD-TV. The United Kingdom's Independent Television Commission (ITC) has led the charge of 3-D imaging systems in Europe. The ITC has invested in a series of projects like Digital Stereoscopic Imaging and Applications (DISTIMA) that are aimed at improving the status of 3-D TV broadcasting. DISTIMA efforts led to the development of an advanced stereoscopic camera and display. Meanwhile, the US Army in the United States has taken gigantic steps in investing into 3-D imaging projects. Studies like the one done by SRS Technologies for the Army have shown that 3D displays are far much better than 2D displays particularly in air traffic monitoring [8]. Such results have prompted TV entrepreneurs like Isaac Blonder to make suggestions of 3D-TV imaging for the Army. Some suggestions were put forward for the Advanced Testing Institute (ATI) to undertake in performing research work on 3-D TV for the Army. Blonder's suggestions were made to enable 3D TV in air and ground observations of battlefields during military operations.

HinesLab in the United States reported that they have developed a system built around a single liquid crystal panel that provides true stereo 3-D images without the use of stereo glasses. Their results among many others show that the ultimate goals of 3-D imaging systems can be achieved in the near future. Their 3D images are formed from the projection of multiple images and can be broadcast in many systems including NTSC and HDTV, which make it easier for transmission over existing television transmission structures. Apart from the fact that HinesLab system uses the liquid crystal display, broad research is in progress in the field of liquid crystal displays (LCDs). Ferroelectric Liquid Crystals (FLCs) are a class of LCDs that have received much research attention because of their potential in 3-D imaging systems. Among other suitable properties for 3-D systems, FLCs have the fastest switching time of all LCD types, they have a wide viewing angle and they have the highest resolution of all LCD groups [8]. FLC devices are projected to drive data rates as high as 10Gbits/s and investigations are continuing on their possible use in holography [8].

The approach taken in researching displays for 3-D images does not necessarily use the same methods worldwide. For example, at Lebdev Physical institute in Russia they have concentrated on the use of neural network algorithms to produce a system they will term neuro-stereo display. In this institute they have also proposed the use of holographic screens and volumetric holographic screens to try and achieve the goals of 3D imaging [8]. At Carnegie Mellon, substantial research has also been done on 3-D imaging with much concentration on encoding, transmission, compression and decompression. The issues tackled at Carnegie Mellon are very important when considering 3-DTV broadcasting. There have been major concerns on how the 3-D data can be transmitted and this can be only possible if the data is compressed. Research work has revealed that the MPEG encoding/decoding algorithms can handle the data rates associated with 3-D imaging. In experimenting with the results of the UK DISTIMA project, the overall data rates of the connection were 10Mbit/s, which is manageable under MPEG standards. Researchers have projected that 3-DTV can be broadcast at 1.5 times the rates of HDTV [9][6]. These projections are similar to the results exhibited by the DISTIMA project.

Autostereoscopic displays can be considered to be the answer in the success of developing 3-D imaging system especially 3-DTV because they eliminate the use of goggles or any other special head wear. McCormick and associates in the United Kingdom have worked on alternative methods of capturing 3-D images using an advanced form of integral imaging. Their method uses one camera and produces an image compatible with the existing 2D displays [12].

Some of the major activities in 3-D imaging systems have occurred at the University of Cambridge. Here, autostereoscopic displays have been developed and 3-D images have been successfully projected [1][2]. The displays developed are multi-view displays as opposed to two-view displays and consists of high speed LCD. It allows the 3-D images to be viewed from different angles and positions. Sharp Laboratories of Europe, NHK and Xenotech of Australia are among two-view enthusiasts. They advocate projecting only two views (one on each eye) but continually monitoring the position of the viewer’s head and adjusting the display so that the views stay visible to either eye. The University of Cambridge demonstrated a 50" autostereoscopic display for the first time in February 1999 in Cambridge, UK [1]. Their display required data rates of 230Mpixels/s to display full-rate video signals. Sanyo Electric of Japan in collaboration with NHK made the world's first commercially available 3-D displays that do not require glasses in 1996. Their displays also produce full screen 2-D images. Research continues to bloom in the field of 3-D imaging systems both in autostereoscopic and stereoscopic systems, although future is pointing towards autostereoscopic systems.

3. System Requirements and Hardware

Figure 1 illustrates the fundamental architecture for a 3D imaging system. The Encoder Subsystem contains 2 cameras for stereo image capture, a disparity estimator and encoder for left/right images correlation and coding, sync circuitry for ensuring synchronization of signals. An Encoder is used for compression of image data. This coder can be a standard (e.g., DCT, wavelet based) or custom compression scheme. This data is then combined or multiplexed for storage or transmission. The Decoder Subsystem is basically the inverse of the encoding system.

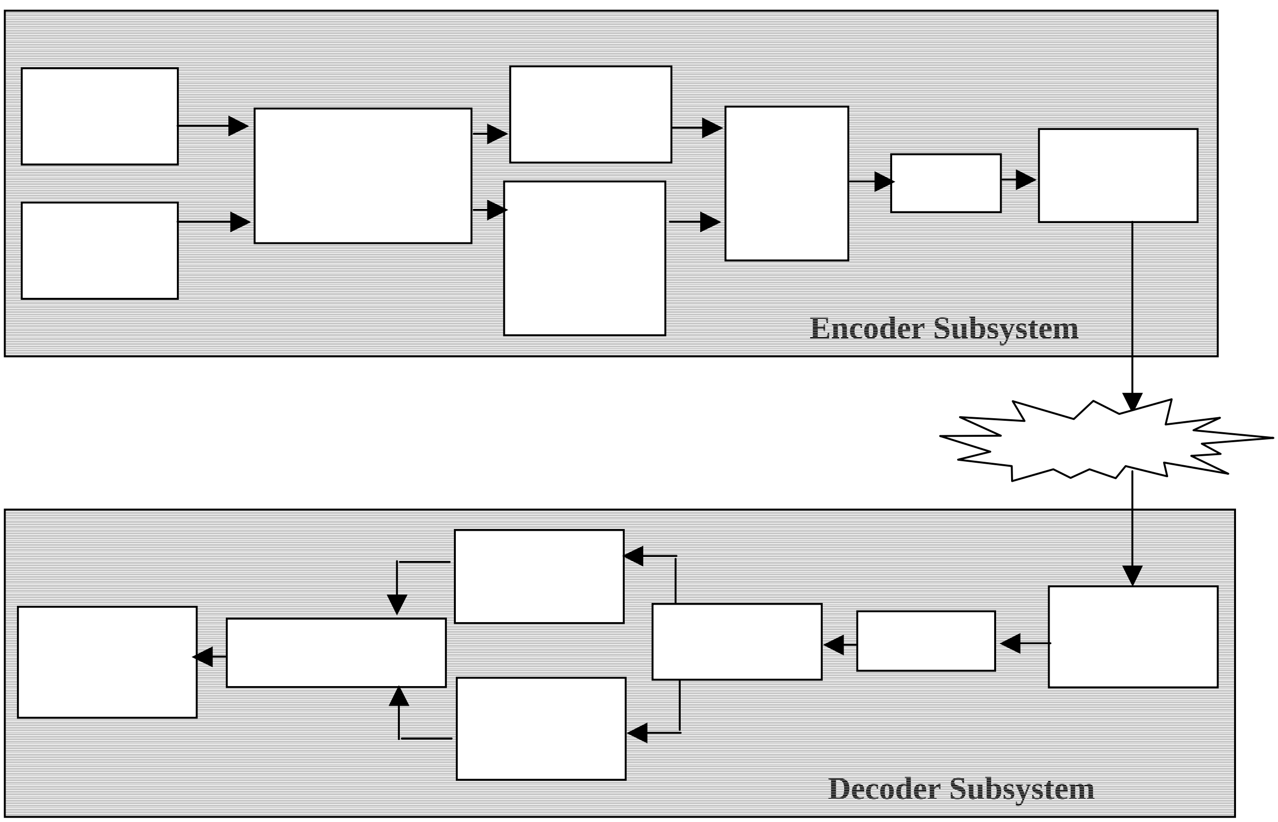

Figure 1: Functional Description of Generic 3D Imaging System

The requirements for full color 3D imaging systems with resolutions of 2048 x 1536 would be around 81 MHz, which is approximately 1.5 times that of HDTV systems (54 MHz) [6]. The entire 3D Image Codec can be implemented using both commercial off the shelf devices such as TI C64x, 62X, or 67x [TI00] and Programmable Logic Devices [14][15][16] as shown in **Figure 2**.

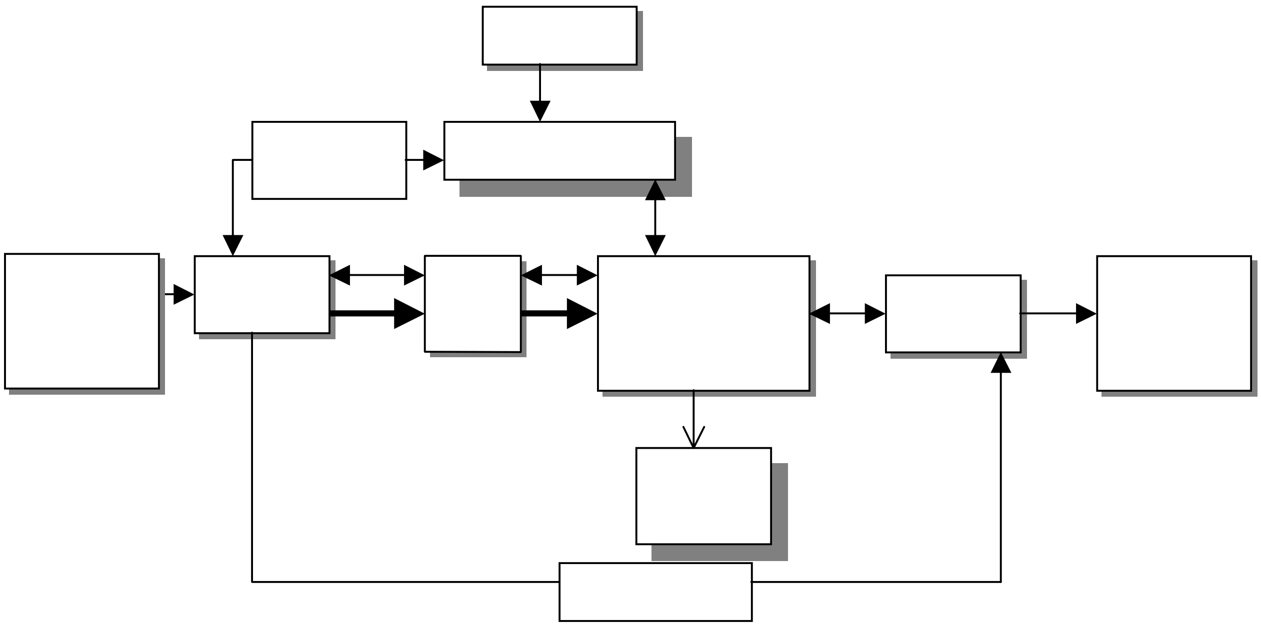

Figure 2: Hardware architecture of Codec unit

Furthermore for transmission of this data will be of extreme importance and lends itself to another area for intense research. Front end components such as ADCs and DACs of transceiver systems will set the overall dynamic range of the system and thus, the resolution that can be observed in the image [17].

The TMS320C64x fixed point DSP delivers performances of up to 8800 MIPS. Its advanced high speed clocking enables rates of up to 1.1 GHz. The C64x offers performances 4x better than the C62x in terms MIPS and clock speed. Advanced instruction packet allows for a 25% improvement in code-size reduction over the C62x. The TMS320C67x floating point DSP has been benchmarked at 1GFLOPS and has a top CPU speed of 167 MHz. The C67x's numerical processing capabilities allow for a wide range of applications including image processing. Table 1 illustrates a comparison between the C64x and the C67x.

	C64x	C67x
MHz	600-1100	150-167
MIPS/MFLOPS	4800-8800 MIPS	600-1000 MFLOPS
16-bit MMACS	2400-4400	300-333
8-bit	4800-8800	300-333
Imaging	Special Purpose Instructions	General

Table 1 Comparision of TI C64x and C67x

4. Discussion and Future Work

This paper has reviewed the current status of the 3D Imaging Systems and described hardware requirements for these systems.

The authors' near term plan is to focus on studying algorithms and architectures (including ADCs and DACs) for dynamic performance characteristics of 3D Imaging Systems. Performance characteristics of ADCs as already begun and with regards to algorithm development, one area of focus that is in the initial stages is a JPEG based 3-D image compression system designed to provide extra data compression to all right frames. This is accomplished by the use of a new comprehensive block based predictive coding scheme as well as a Progressive Color Map Matching (PCMM) algorithm. This scheme accounts for discontinuity and occlusion. For an occluded area, occluded points are independently encoded, while for non-occluded areas, the points are passed into a dynamic programming algorithm to calculate the disparity vectors used in predictive coding. This compression system is most effective with color stereo images and is also effective in compressing grayscale stereo images. This scheme has the potential to be applied to other compression technologies such as wavelets.

PCMM 3-D compression system can even be implemented with 3-D video streams. For this case, redundancy not only occurs within each stereo pair but also within subsequent pairs in the video stream. Predictive coding is employed not only on each stereo pair but also on a set number of pairs that are stored within a buffer. Similarly, the PCMM algorithm operates not only on a stereo pair but also on a set number stored within the buffer. This system inherently imposes a short time delay during the transmission of a 3-D image stream. Depending on the nature of the stream the length of the delay, or the size of the buffer, the greater the compression factor and restoration quality. To obtain even further compression with video streams, a feature of the JPEG compression engine could be exploited. Abbreviated data streams are streams of compressed images that are stripped of their quantization and Huffman tables. More accurately, for similar images, one head image will contain all the tables for the subsequent images, making it possible to save space that would other wise be wasted storing very similar tables for each image.

We also plan to implement this system using one of TI's DSPs and some Programmable Logic Devices as co-processors. The benefits include platform independence, faster compression time, and portability.

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