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An Analytical Approach of Mars Rovers by Using GPU Technology and Genetic Algorithm

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***Abstract*-** Mars Rovers are the unmanned machines on planet MARS which are send to analyze and provide details about the planet. GPU and Genetic Algorithms are upcoming technologies used in Mars Rovers for analyzing and sending the data back to the Earth base station. GPU stands for Graphics Processing Unit in which Image compression is the basic layout of the technology. Image compression involves WAVELET transform and Image segmentation involves genetic algorithm. This paper focuses on introducing the GPU technology and Genetic algorithm and methods involved in it which are key for space communication in the near future.

***Index Terms*-** GPU technology; GeForce; Genetic Algorithm; Wavelet Transform(WT); Wavelet; Pixels; Inverse WT**.**

I. INTRODUCTION

GPU is an acronym for GRAPHICS PROCESSING UNIT. It is a technology which increases rate of operation in the field of science and its applications. CPU and GPU is a powerful combination because as CPU consists of a few cores optimized for serial processing, and GPU consists of thousands of smaller, but efficient cores which and is designed for parallel performance [1, 15, 16].

The mathematically-intensive tasks, which may strain CPU, GPU technology lifts up the burden of CPU and frees up cycles which can be used for other applications.

The first company to develop the GPU was NVIDIA. NVIDIA's GeForce256 is the first to be developed which is capable of billions of calculations per second, and processes a minimum of 10 million polygons per second. It has over 22 million transistors, as compared to 9 million of Pentium III version of INTEL.

GPU technology also involves workstation versions called the Quadro, by which over 200 billion operations per second can be processed and are delivered at the rate up to 17 million triangles per second.[2]

The GeForce card is compatible with other graphic cards namely APIs, OpenGL, Microsoft's DirectX, Intel's Accelerated Graphics Port (AGP) and AMD 's 3D..GPU clock is known as Engine clock and is measured in megahertz (MHz)[1, 15]

In the field of computers genetic algorithm(GA) is a basic search which mimics the process of natural selection. The heuristic search (also sometimes called a meta heuristic) is used to generate useful solutions for optimization and search problems It is an artificial intelligence used by most intelligent machines[3].

Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover[3].

II. FEATURES OF

GPU TECHNOLOGY

The GPU technology consists of LLNL which has fully functioning supercomputing environment. NVIDIA's Compute Unified Device Architecture (CUDA) technology is a hardware specification for its General Purpose Graphics Processing Units (GPGPUs). GPGPU's can also refered as "GPU" as GPU are Single Instruction, Multiple Thread (SIMT) devices [16].

GPU computing is fundamentally different from CPU computing. GPU technology is also known as "stream processing" as it focuses on very high numbers of floating point computations. The computer algorithm with 10x, 20x or 100x speedups even compared to a modern multi-core CPU follow this technology. GPU is five times more efficient than a CPU as GPU optimizes results and enhances CPU performance.

The Tesla M2050 and EDGE of GPU technology installed at 200 node graphics cluster, are capable of 515 double precision GFLOPS in GPU technology are capable of 1.03 TFLOPS which have double precision or 2.06 TFLOPS of single-precision which shares global memory between 448 cores or 6.25 MB per core[4]

GENETIC ALGORITHM

As in case of humans genes play an important role in the transmission of characters to off springs from parents and best suitable healthy genes are selected by the numerous segments of chromosomes ,in the same way Genetic algorithm (GA) is a method in which noise free segments are used to construct an image. These segments are obtained from different images of same object. In genetic algorithm fitness of segments are analyzed. The principle of Natural Selection is also applicable in GA where only noise free segments are selected and rest are dropped. An image formed using GA is called as Generation which can be further used to form new generations. GA requires following two aspects

- Genetic representation of the solution.
- A fitness function to evaluate the segments [12,13, 14].

III. ADVANCEMENT IN GPU TECHNOLOGY

Earlier in the field of computers and graphics involved a shared software which was used to define the graphics layout of the computers and mostly all graphics were driven by software DirectX. This software used to couple the main memory and secondary memory of the computers to execute particular application. Different versions of DirectX performed different functions and performed graphics analysis[5].As the technology advanced a dedicated graphics card introduced in CPU which had its own inbuilt memory options and RAM was saved both from timeless usage and over utilization. These cards where named as GeForce. In the MARS rovers these cards provide both color management and memory space consideration which are the key constrain for Image compression. Table 1 describes the advancement in dedicated cards and technology involved in them [5].

TABLE 1: GPU TECHNOLOGY ADVANCEMENT

YEAR	GPU TECHNOLOGY	TRANSISTORS
1995	NV1	1million
1999	GeForce 256	22 million
2002	GeForce4	63 million
2003	GeForceFX	130 million
2004	GeForce6	220 million
2005	GeForce7	302 million
2006-2007	GeForce8	754 million
2008	GeForceGTX200	1.4 billion

IV. METHODOLOGY OF GPU TECHNOLOGY

In the field of communication this technology leads to graphical analysis of signals and helps in color management of the input data. In Mars rovers GPU technology helps in maintaining color strength of images taken by it and compresses the image so that main memory can accommodate large amount of data in the form of images taken by the camera of a rover. The sequential steps where GPU technology in a rover is used

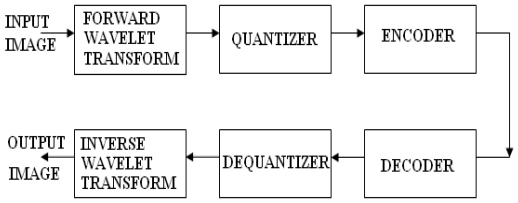
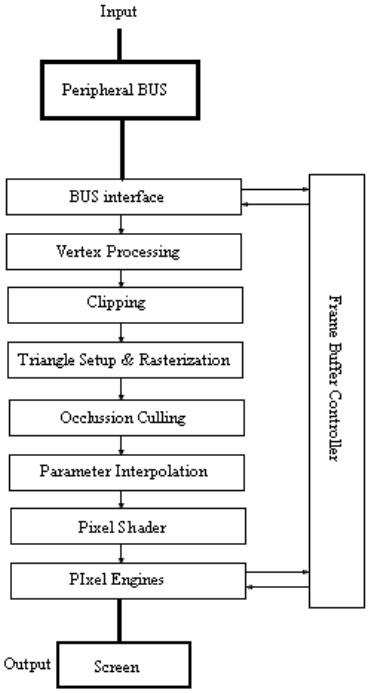


Image Compression performed by a ROVER

In GPU technology graphics pipeline is a key method to analyze and compress image using Wavelet transform

Graphics pipeline is a fundamental concept in computer graphics and refers to a series of interconnected stages through which data and commands describing a scene in an image by which a rover can built an image and process it to the PHOTOREALISTIC model of the object on MARS [6,7]. Graphics pipeline also helps in adapting the images on the screen close to the human eye observations. GPU helps in modifying image and remove noisy signals by the use of wavelets with respect to time for analyzing, compressing and maintaining nature and layout of PIXEL of an image.

The basic methodology of GPU technology is:



Flow Chart of Methodology of GPU Technology

a) Bus interface It interfaces with the system for sending and receiving data by processing commands[7].

b) Vertex Processing It converts each vertex into a 2D screen position, and color is determined by lighting process. A programmable vertex shader is used which enables custom transformations for effects like warping, deformations of a shape. By vertex processing, vertices are transformed to screen space [7].

c) Clipping It removes the parts of the image which are invisible in the 2D screen view like backsides of objects, areas which the applications or window system do not cover which are thus, deleted or clipped [7].

d) Triangle Setup Collected vertices are converted into triangles and information is generated for every attribute of every pixel associated with the triangle [7].

e) Rasterization In this triangles are filled with pixels which are known as "fragments" which may or may not wind up in the frame buffer [7].

f) Occlusion Culling It removes pixels that are hidden or occluded by other object [7].

g) Parameter Interpolation In this values for each fixed pixel is computed on the basis of color, fog, and texture [7].

h) Pixel Shader In this stage textures and final colors are added to the fragments. In this stage a programmable pixel

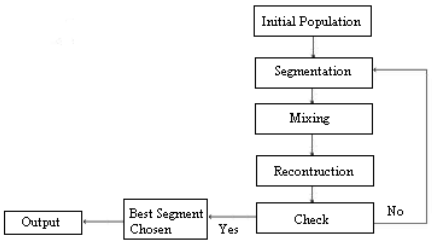
shader is used to combine pixel's attributes and textures in a user-defined way for generating custom shading effects in the image [7].

i) Pixel Engines These are used for mathematically combination of final fragment colors, coverage and degree of transparency with the existing data stored at the associated 2D location in the frame buffer for producing the final color for the pixel [7].

j) Frame Buffer Controller The frame buffer controller interfaces the physical memory which stores the actual pixel values. The frame buffer memory is often used to store graphics commands, textures and other attributes associated with each pixel [7].

GENETIC ALGORITHM

In a genetic algorithm, an object is segmented and a population of solutions are obtained for a problem and these are evolved toward better solutions whose properties can be altered. These solutions are represented in binary as strings of 0s and 1s.In this algorithm solutions are obtained from a population of randomly occurring segments and by an iterative process whose ,final results obtained are termed as a generation. In each generation, the fitness of solution in the population is evaluated and the most fit solution are stochastically selected from the population, and each individual's solution is modified (in similar way as in humans chromosomes are recombined and possibly randomly mutated) to form a new generation. The new generation of solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population [2].
A standard representation of each segment or solution is as an array of bits of 0s and 1s.GA has main property has similar genetic representations as in humans in which appropriate segments of chromosomes are recombined. In the same manner noiseless or less noisy segments are combined to form a solution in GA which are convenient as they are aligned due to their fixed size, which facilitates simple crossover operations.



Methodology of Genetic Algorithm

GA representations are explored in genetic programming and graph-form representations in human chromosomes are also explored in evolutionary programming of genetic algorithm in which different segments are analyzed.

V. ANALYTIC APPROACH

In the analytic application to MARS ROVERS featuring Satellite Communication both GPU and GA contribute to image compression and image segmentation respectively.

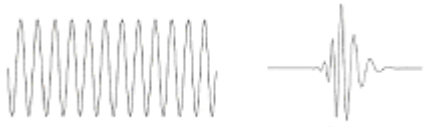
Image compression is a technique to reduce image size, PSNR value and number of pixels per block keeping W/L ratio same in order to increase the capacity of file storage and to improve the losses introduced in communication process.

Image segmentation is a process in which proper segments are selected to reconstruct the image which are less noisy and are close to object in the same way as in a human chromosomes are segmented to form an offspring .A composite image is formed by segments of different images taken of same object by MARS ROVERS.

Both the techniques GPU technology and GA are used by MARS rovers to communicate the EARTH base station and connect both the planets.

Image Compression

Compression of an image taken by the Rover is a technique in which W/L of the image, number of pixels and resolution are maintained. In the rovers graphics nature of the image is maintained and memory constrains are modified. In image compression size of the image is changed so that available memory can be effectively utilized and speed of operation is enhanced. The graphics layout of the image is modified by GPU technology and compression is obtained by transforming the image by using Wavelet transform. This transform transforms image into another form of representation. It does not change the information content present in the image. Wavelet Transform provides a time-frequency representation of the image [17].
The Wavelet transform involved uses small wavelets of finite energy and multi resolution techniques for analyzing different frequencies. Wavelets used in this transform are localized waves and have energy constrains in both time and space.



a WAVE and a WAVELET

In the image compression using Wavelet transform image is divided into number of signals and each signal to be analyzed is multiplied with a wavelet function which is acts as a window function and then the transform is computed for each segment generated. Value of the output of the system using Wavelet transform depends upon width of the wavelets used which scale and translate the signals.

Nature of timing sequences of wavelets transform may be Continuous or Discrete. The window function of continuous wavelet transform from (1).

$$Xwt(\tau, s) = \frac{1}{\sqrt{|s|}} \int x[t].\psi^*\left(\frac{t-\tau}{s}\right) \quad (1)$$

The continuous wavelet transform is the sum over all time of scaled and shifted versions of the mother wavelet ψ. The coefficients in continuous wavelet transform are calculated from (2).

$$C(s, \tau) = \int f(t)\psi(s, \tau, t)dt \quad (2)$$

in which τ is proportional to time information and s is proportional to inverse frequency information[8].

Equation 3 gives window function of discrete wavelet transform.

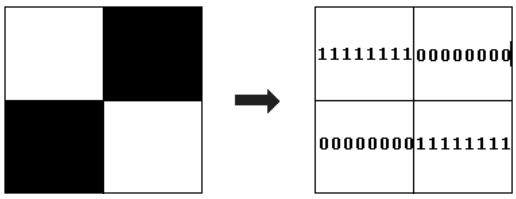
$$Xwt(\tau, s) = \frac{1}{\sqrt{|s|}} \psi(\frac{t-\tau}{s}) \quad (3)$$

The Discrete Wavelet transform is calculated using above window function and respective transform function is (4).

$$y[n] = (x * g)[n] = \sum_{\infty} x[k] g[n-k] \quad (4)$$

The Discrete Wavelet Transform (DWT), is based on sub-band coding and yields fast computation of Wavelet Transform. It is easy to implement and also reduces the computation time and resources required [17].

In image compression and processing techniques there are 256 intensity levels or scales in which 0 is black and 255 are white. Each level is represented by an 8-bit binary number so black is 00000000 and white is 11111111[8].



Intensity level of an Image

At the receiver end decompression is performed using inverse Wavelet transform (WT) and original image as by (5).

$$x(t) = \int_0^{\infty} \int_{-\infty}^{\infty} \frac{1}{a^2} X_W(a,b) \frac{1}{\sqrt{|a|}} \overline{\psi}\left(\frac{t-b}{a}\right) dbda \quad (5)$$

where $\overline{\psi}(t)$ is a dual function of $\psi(t)$ [9].

$$\psi(t) = \begin{cases} 1 & (0 \le t < \frac{1}{2}) \\ -1 & (\frac{1}{2} \le t < 1) \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

Equation (7) is the inverse DWT used by rovers to decompress images is given by[10,11].

$$f(n) = \frac{1}{\sqrt{M}} \sum_{K} W_{\varphi}(j_o, k) \psi_{j,k}(n) + \frac{1}{\sqrt{M}} \sum_{j-jo}^{\infty} \sum_{|K} W_{\psi}(j,k) \psi_{j,k} \quad (7)$$

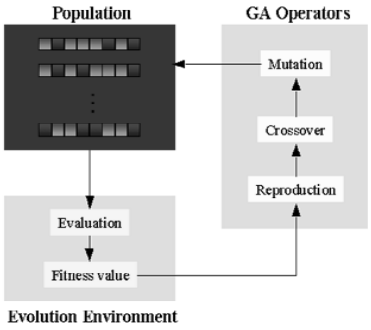
Therefore image compression algorithms aim to remove redundancy in data in a way which makes image reconstruction possible and redundancies are removed. It is a compression technique which aims to reduce the requirements of storage space, transmission bandwidth and transmission time and helps in quicker transmission and decompressed at receiver

Image Segmentation

Image segmentation is a process of dividing an digital image into multiple segments or parts. According to some homogeneity criteria set of pixels, pixels in a region are similar in both segments and un segmented image in respect to color, intensity or texture and it helps in locating and identifying objects and boundaries in an image. The basic goal of image segmentation is to simplify or change the representation of an image into something that is more meaningful and easier to analyze. In the image segmentation an image is segmented in number of segments and a new image is reconstructed using segments so that a lossless or less noisy image can be formed. It is basically performed by use of Genetic algorithm which analyses and selects less noisy segments for reconstruction.

Genetic algorithm is a method of dividing parental image into segments and from the population of segments it judges and create an offspring image with best fitted valued segments. Major GA operators are [12, 13, 14]

- Mutation
- Crossover
- Reproduction or reconstruction



GA rule for Image Segmentation

The choice of a segmentation technique over another and the level of segmentation are decided by the particular type of image and characteristics considered but all have same flow diagram.

A simple GA algorithm has following steps:

- Start with a randomly generated population of n bit segments of images
- Calculate the fitness f(x) of each segment in the population.
- Repeat the steps until an image is reconstructed using best fitted segments.
- We select a pair of parental images from the current population of images which on selection has least noise effect.
- With probability, crossover the pair at a randomly chosen point to form two new reconstructed images as offspring. If no crossover takes place, form two offspring that are exact copies of their respective mother image.
- Mutate the two new reconstructed images at each locus with probability and place the resulting segments in new population.
- Replace the current population with new population of reconstructed images[12,13,14]

This results in an image segments that collectively cover the entire image or a set of contours extracted from the image.

The quality of segmentation depends upon the quality of image, gray level, texture, color, depth [12].

VI. APPLICATIONS

GPU technology is primarily used for analyzing and maintaining graphics layout of 3-D applications, and redraws 3D objects on 2D screen. It also creates lighting effects and transforms objects every time a 3D scene[2] Practical application of image segmentation range from filtering of noisy images, medical imaging, locating objects in satellite images , iris recognition, fingerprint recognition[4].

VII. CONCLUSION

MARS rovers the unmanned machines involve image compression and image segmentation for sending data back to the Earth base stations. These techniques are involved for effective utilization of memory and removing noise effects so that true information can be communicated from the captured image of the events going on planet MARS.

VIII. ACKNOWLEDGMENT

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