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Design and Development of On-Board Earth Resources Detection System Based on FPGA and LabVIEW for Remote Sensing Application

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Abstract

This paper presents system development for the detection of earth resources such as a water, vegetation and land for the satellite application. Satellite imaging sensors generate mass volume of data at very high speeds. On the other hand, storage capacity and communication bandwidth are crucial parameters for satellite resources. Here we have proposed the system that can be used on board to extract relative information from the image and can send out the required (obtained) results to the ground system (Result of pixel information whether it contains water/vegetation/land). The system can be used for the saving of on board satellite resources such as memory storage, power and communication bandwidth. The detection of earth resources are based on their reflectance value. For the analysis of proposed detection algorithm LabVIEW based simulation has been carried out for the detection of Land, Water and vegetation from their reflectance value. Same algorithm has implemented in FPGA for the real time implementation using SPARTAN XC3S500e-4vq100 FPGA board. The results are accurate and matched with the simulation results performed in LabVIEW.

Keywords: Land, Water, Vegetation, Field Programmable Gate Array (FPGA), LabVIEW (Laboratory Virtual Instrument Engineering Workbench)

1 Introduction

Remote sensing is being used for the detection and classification of objects on earth such as land, vegetation, water, sand, dessert, snow. This information can be used for the mapping land use, archaeological investigation, military observation, agriculture, soil mapping, city planning, forestry, geographical surveying etc. [1].

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These operations are generally performed by satellite in store and forward modes. It means first image is captured by satellite camera (sensors), stored that image in onboard memory and send the resultant data to the ground subsystem with the use of downlink channel[1].This process utilizes onboard satellite resources such as memory and communication bandwidth for the transmission of resultant data. To utilize better resources of satellite, it is better to use on-board system instead of store and forward mode. In which processing of required data is done on satellite and send out the resultant data to the ground station (for better utilization of channel bandwidth).

To detect geophysical object such as vegetation, water, land, snow, cloud at onboard, it is important that it should operate with high computational accuracy [2]. In modern satellite remote sensing technology an algorithm implementation to detect these geophysical objects is carried out at the ground subsystem level [1]. Ordinary methods to detect these object based on individual or combination of method such as spectral contrast, radiance temporal contrast, and spatial contrast. A motivation behind implementation of algorithm for detection of geophysical object on hardware is that it can be used on onboard to reduce transmission of inconsequential image data to the ground subsystem.

There are number of possibilities to implement the algorithm on hardware such as DSP, FPGA, Microcontroller, Processor etc. FPGA has a unique advantage such as reconfigurable logic cells, ability to perform logical operation according to user application, ability to handle parallel operation. It can potentially reduce the delay between image capture, analysis and action. It also reduces onboard storage and downlink capacity requirements [3].

The flow of paper is as follows. Section II describes the related work that has been previously done for the detection of land, water and vegetation detection based on reflection. Section III describes algorithm outline for the detection of water, vegetation and land and simulation results using LabVIEW for the analysis and verification purpose. Section IV describes the hardware description and result of algorithm implementation in hardware.

2 Literature Survey

The detection of earth resources have wide range of applications such as an environmental monitoring, climate changes studies, numerical weather forecast model, natural hazard monitoring, agriculture and forestry [4]. A Basic concept related to the reflectance quantities are classified in literature [5]. Reflectance term such as Bidirectional reflectance distribution function (BRDF), Hemispherical–directional reflectance factor (HDRF), Directional–hemispherical reflectance (DHR), Bi hemispherical reflectance (BHR), albedo are explained in this literature with details. Review of water body extraction using satellite remote sensing is presents in literature [6]. A tree species classification from high resolution colour infrared aerial images and its digital surface model is described in literature [7]. The identification strategy for the tree species includes detection of vegetation area, segmentation of vegetation area according to their height followed by identification of individual tree.

To find out the spectral signature of objects like land cover classification and the vegetation index on low contrast satellite images using normalise difference vegetation index technique is present in literature [8]. Singular value decomposition and discrete cosine transformation techniques are used for the features extraction on low contrast satellites images. Vegetation detection algorithm for the close range images based on texture features and naive bayes classifier is presented in literature [9].To prove the validity of the method they have compare the method with the visual cognition features. To eliminate vegetation's interference with the landslide deformation monitoring the result of vegetation detection is applied to landslide monitoring [9]. Huge amount of studies are performed on satellite and aerial images for the detection of vegetation [9-11].

It is mentioned in [12] that both NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) method do not use more than two bands to calculate index which misrecognize some non-water features as their index values fall close to index values of water features. Hence, Hongxu has defined water detection method which is combination of three methods NDWI, NDVI and mathematical morphology [12]. Min Li has proposed method that uses locally excitatory globally inhibitory oscillator networks which can extract coherent water body without the analysis of water and its surround environment [13]. Hanqiu Xu has proposed modified NDWI algorithm which can discriminate open water features from non-water features while efficiently suppressing and even removing built-up land noise as well as vegetation and soil noise [14].

3 Algorithm Outline and Simulation Results

Fundamental source of energy is the sun and it radiates the electromagnetic energy in earth atmosphere. Some of this energy absorbed in earth surface and some are reflected back. It is possible to detect earth resources from its reflectance value. Reflectance value of any object can determined from the albedo (reflectance radiation from earth surface). This albedo can be figure out by taking ratio of reflectance to the total radiation hitting to the surface. Figure 1 shows the reflectance value of different object from the earth surface . Additional detail of reflectance value is tabulated in Table I.

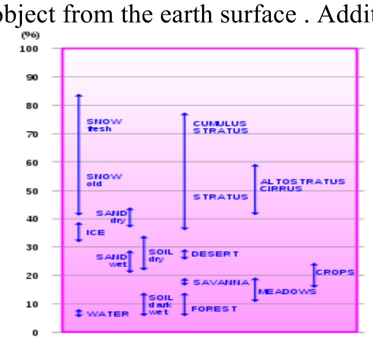


Figure 1: Reflectance value of different object from earth surface

Surface	Reflectance (%)
Soil	5-40
Grass	16-26
Forest	15-25
Water	3-10
Snow	40-95
Ice	30-50

Table 1: Reflectance Value of Different Object Relative to Earth Surface

3.1 Algorithm Development and Analysis

With the analysis of different images in LabVIEW, we have derived reflectance range of red, green and blue components of individual pixel for land, water and vegetation. We have found that for detecting vegetation red component of individual pixel varies in range of 25 to 50, green component of individual pixel varies in range of 20 to 60; blue component of individual pixel varies in range of 25 to 45 . Same way for water the pixel has value of red component in between 30 to 60, value of green component in between 35 to 60, and Value of blue component in between 30 to 90. For the land red component varies in range of 90 to 110, green component varies in range 80 to 110; blue component varies in range of 60 to 110.Further to this, we have derived the ratio of red to green component and ratio of blue to green components of individual pixels for the individual objects. The reflectance range and ratio of red/green and blue/ red are tabulated in the table 2. The complete flow of the algorithm for the detection of earth resources is shown in figure 2.

Surface	Reflectance						Ratio	
	Minimum			Maximum			R/G	B/R
	R	G	B	R	G	B		
Land	90	80	60	110	110	110	1 <= R/G < 1.15	< = 1
Water	30	35	30	60	60	90	0.8 < R/G >=1	> = 1
Vegetation	25	20	25	50	60	45	0.8 < R/G <1.3	< = 1

Table 2: Analysis of various Ranges of values for detection of land, water and vegetation

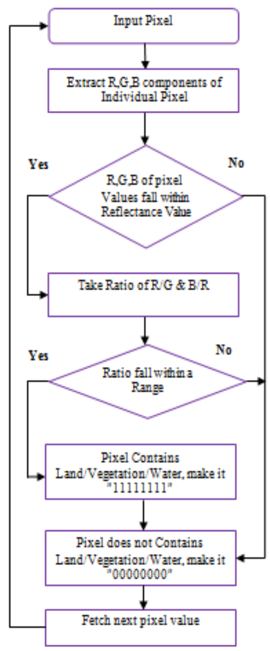
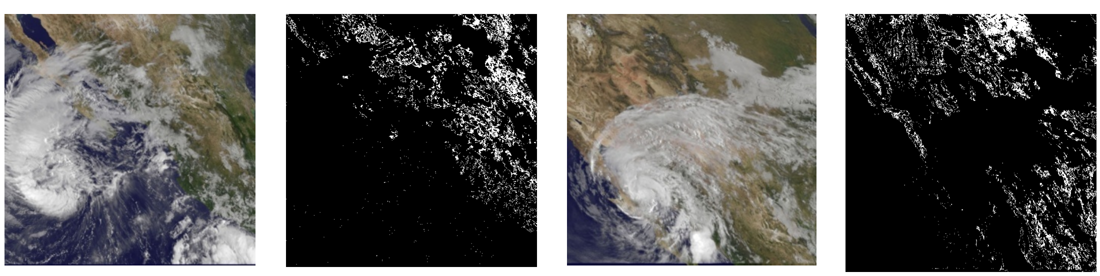


Figure 2: Flow diagram of algorithm implementation

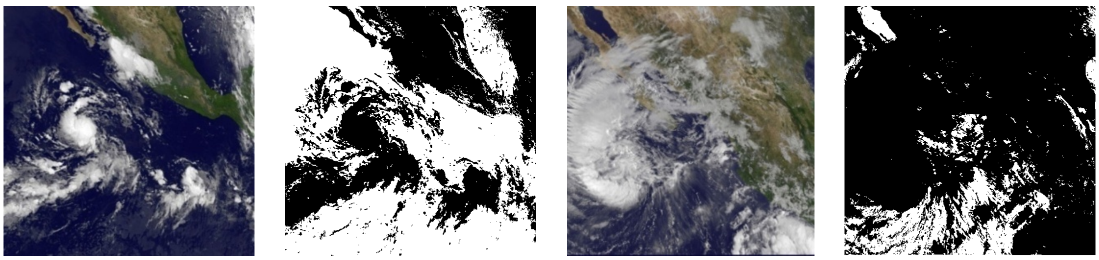


(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (b) Simulation result of figure (a) in Lab VIEW (8 bit image of 512*512 pixels) for land detection (white spot indicates presents of Land in the IMAGE) (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Simulation result of figure (c) in Lab VIEW (8 bit image of 512*512 pixels) for land detection (white spot indicates presents of Land in the IMAGE)

Figure 3 : Simulation Results of Land detection in LabVIEW

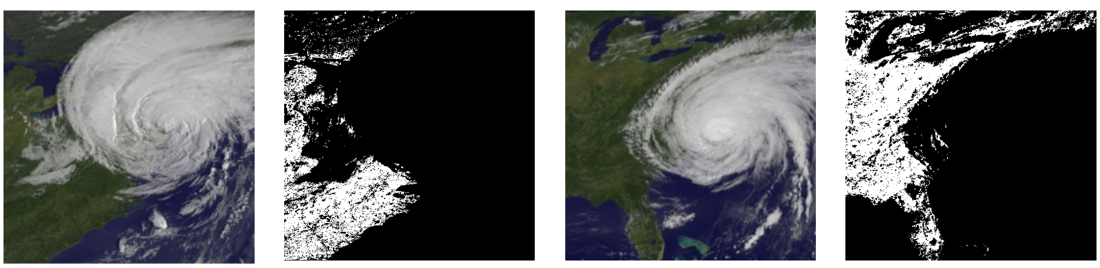
Simulation results for the detection of land, water and vegetation detection is shown in figure 3,figure 4 and figure 5 respectively . LabVIEW is used for the simulation purpose. First we have extracted value of Red, green, and blue components from the individual pixels. Based upon this we have decided the reflectance range value of R,G,B component of individual pixels. Following to this step the ratio of red component to the green component and ratio of blue component to the red component of individual pixel are taken.



(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (b) Simulation result of figure (a) in Lab VIEW (8 bit image of 512*512 pixels) for water detection (white spot indicates presents of water in the IMAGE) (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Simulation result of figure (c) in Lab VIEW (8 bit image of 512*512 pixels) for water detection (white spot indicates presents of water in the IMAGE)

Figure 4: Simulation Results of Water detection in LabVIEW



(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (b) Simulation result of figure (a) in Lab VIEW (8 bit image of 512*512 pixels) for vegetation detection (white spot indicates presents of vegetation in the IMAGE) (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Simulation result of figure (c) in Lab VIEW (8 bit image of 512*512 pixels) for vegetation detection (white spot indicates presents of vegetation in the IMAGE)

Figure 5: Simulation Results of Water detection in LabVIEW

4 Hardware Implementation

We have designed and developed external board that will work as a daughter board of FPGA. It contains 2 SRAM (for the storage purpose with the configuration of 2M x 16), interface section to connect board with sensor (for future use) and for the connection of system with other system (for the data transmission purpose). KETHLEY 2230-30-1 regulated D.C. power supply is used to deliver supply voltage to FPGA and SRAM. NI LABVIEW 9 is used for the acquisition of an image and exhibit the end results. RS232 serial communication is used for the communication between FPGA board and LABVIEW. A basic block diagram of hardware implementation is shown in figure 6. An image of 512 x 512 pixels of 32 bit resolution is first sent from LABVIEW to FPGA using RS232 serial communication at the speed of 500 KBPS. FPGA has only 360K on chip internal memory, so first image is stored into external SRAM (access time of SRAM is 65 ns). To extract R, G and B component of individual pixel, pixel by pixel read operation is performed. The implementation steps for the detection of earth resources are same that is described as flowchart in figure 7. The results of the pixel are transmitted to LabVIEW for the display purpose using RS232 serial communication at a speed of 500 KBPS.

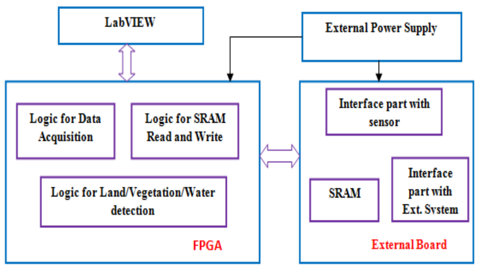


Figure 6: Basic Block of Hardware Implementation

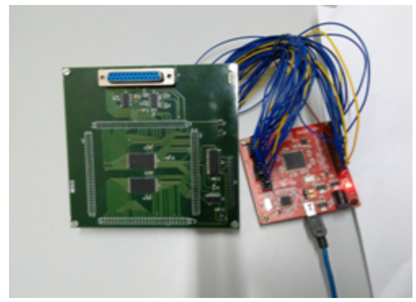
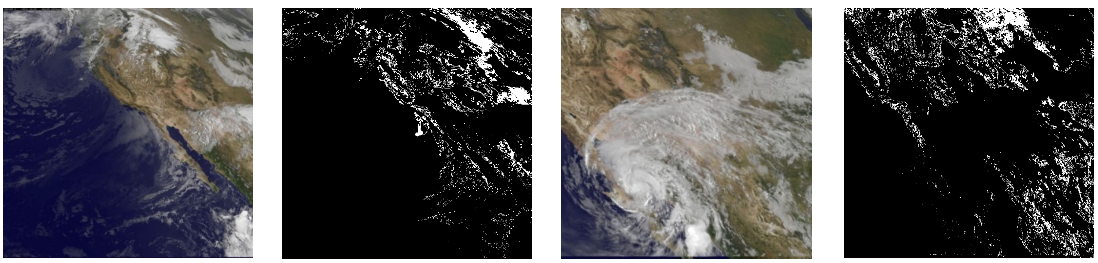


Figure 7: Hardware Setup for System implementation

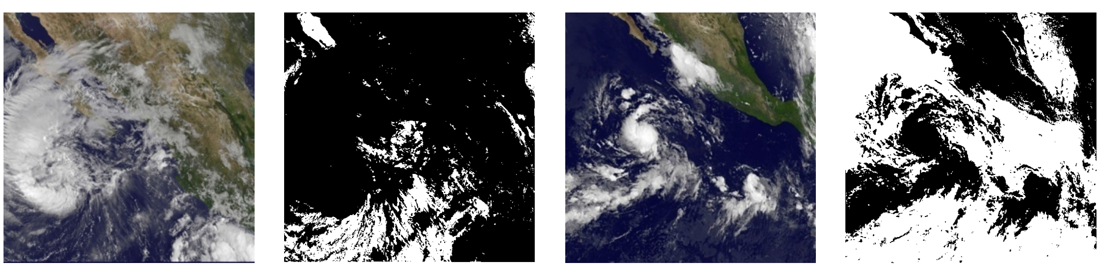
The result of an algorithm implementation for the land, water and vegetation detection in hardware is shown in figure 8,figure 9 and in figure10 respectively.



(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (b) Results in Hardware of figure b (8 bit image of 512*512 pixels) for land detection (white spot indicates presents of Land in the IMAGE) (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Results in Hardware of figure c (8 bit image of 512*512 pixels) for land detection (white spot indicates presents of Land in the IMAGE)

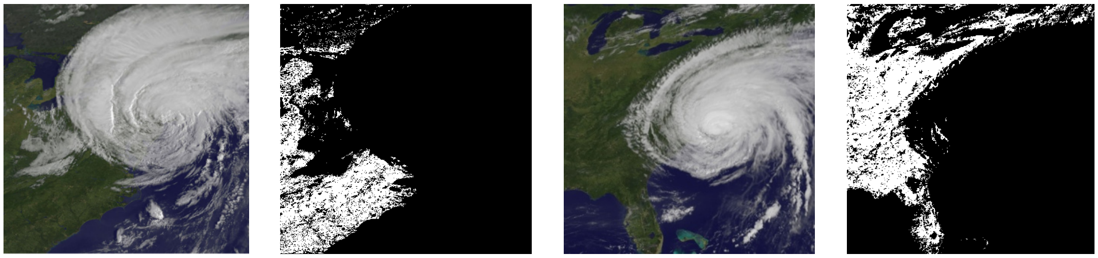
Figure 8: Results of algorithm implementation in hardware for land detection



(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) of Baja California (b) Results in Hardware (8 bit image of 512*512 pixels) for water detection (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Results in Hardware (8 bit image of 512*512 pixels) water detection

Figure 9: Results of algorithm implementation in hardware for water detection



(a) (b) (c) (D)

(a) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (b) Results in Hardware (8 bit image of 512*512 pixels) for vegetation detection (c) 32 bit image of NOAA's GOES satellite (512 * 512 pixels) (d) Results in Hardware (8 bit image of 512*512 pixels) vegetation detection

Figure 10: Results of algorithm implementation in hardware for vegetation detection

4.1 Result and Analysis

For the comparison purpose, we have compared the results implemented in hardware with the simulation results of LabVIEW, It shows more than 90 percents of results are matched with the simulation results. Device utilization summary of FPGA is tabulated in table 3.

Logic Utilization	Used	Available	Utilization (Percentage)
Number of Slice flip flops	438	9312	4
Number of 4 input LUTs	521	9312	5
Number of occupied slices	473	4656	10
Total number of 4 input LUTs	845	9312	9
Number of bonded IOBs	47	66	71
Number of BUFGMUXs	3	24	12
Frequency of operation	32 MHz		

Table 3: Utilization of FPGA resources

5 Conclusion

A detection of earth resources such as land, vegetation and water are simulated and implemented in the hardware based on its reflectance value. LabVIEW is used for the simulation purpose and hardware implementation is carried out in FPGA. From the results, it is cleared that the proposed algorithm performs very well for detection of land, water and vegetation. All the simulation results of LabVIEW are compared with FPGA results shows the more than 90% accuracy of algorithm. The utilization of resources on hardware with this algorithm is very less and also the total power consumption of the system is around 400mW. It is further possible to detect other earth resources such as cloud, snow, sand etc with the use of same algorithm according to reflectance values of objects. It is possible to use the proposed system on-board (satellite) with the optic sensor configuration.

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