REMOTE SENSING ON GPU: A CASE STUDY

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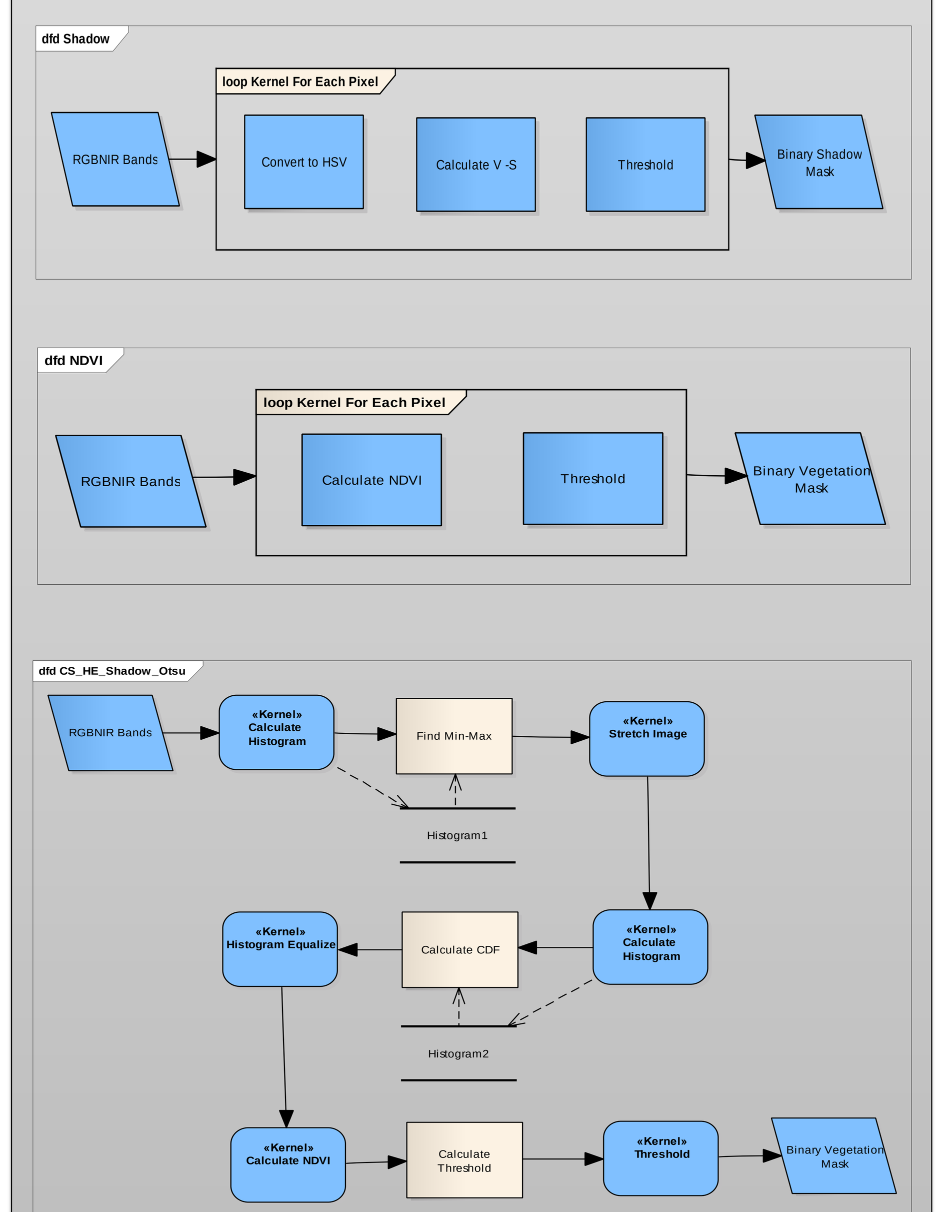
Abstract

Satellite images have become widely available; as a result there are increasing number of commercial applications utilizing these images. Satellites provide data in different wavelengths and they have higher resolution and larger data size compared to typical images. Running complex algorithms on satellite images for large data volumes is highly time consuming using CPUs. Processing of satellite imagery data can be speeded-up using General Purpose Computation on Graphics Processing Units (GPU) instead of Central Processing Units (CPU). In this paper, performance of shadow detection and vegetation detection algorithms are investigated and their performance on GPU and CPU are compared. Results show that up to 10.2 times speed up could be achieved using GPU.

General View of The System



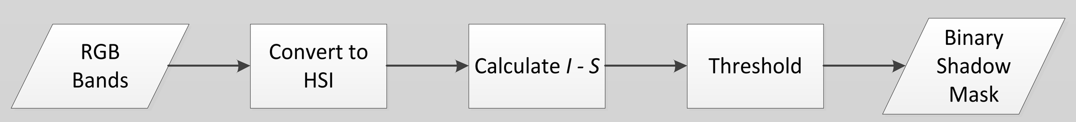
Implementation Details

In this work, common satellite image processing algorithms namely shadow detection and vegetation detection as well as pre-processing steps (contrast normalization and histogram equalization) are implemented.

Shadow Detection

Manmade Objects Casts Shadows

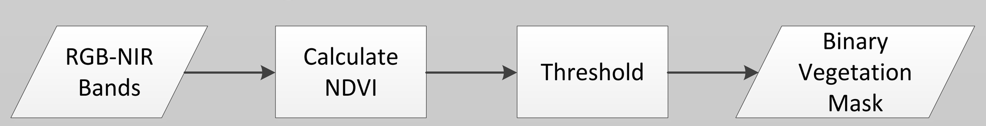
Aerial images contain shadows which causes loss of radiometric information in segmentation, 3D scene reconstruction and registration. Existence of shadows degrades performance of segmentation which is required to separate objects from background for target detection algorithms.



Algorithm 1: Shadow Detection.

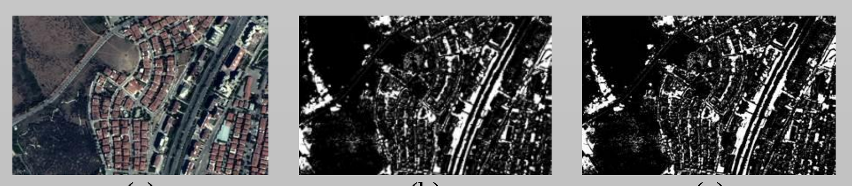
- Image is converted into HSI Color Space.
- I and S values are compared for shadow detection.
- I-S difference is thresholded for detecting shadows.

Vegetation Detection



Algorithm 2: Vegetation Detection

- NDVI Index is calculated.
- NDVI difference is thresholded for detecting Vegetation.

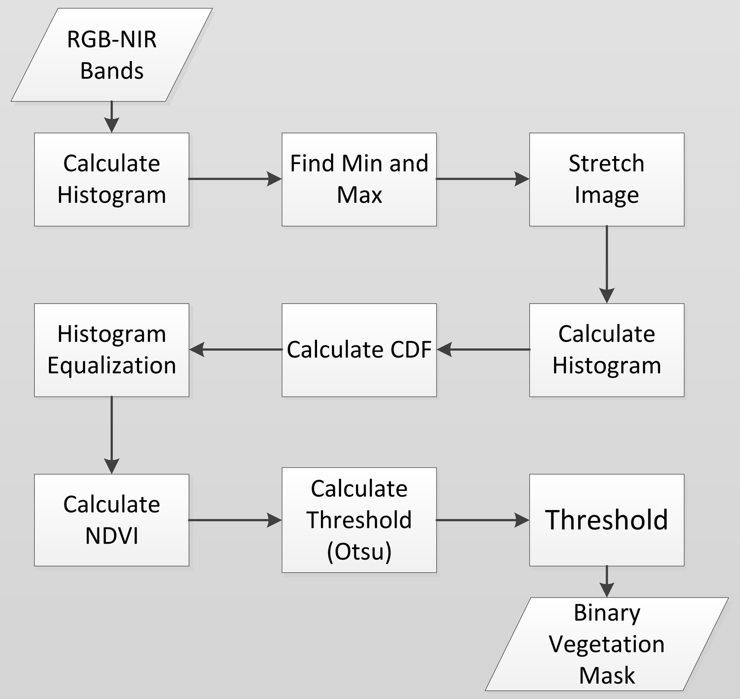


(a) Input Image, (b) CPU Implementation Vegetation Mask, (c) GPU Implementation Vegetation Mask

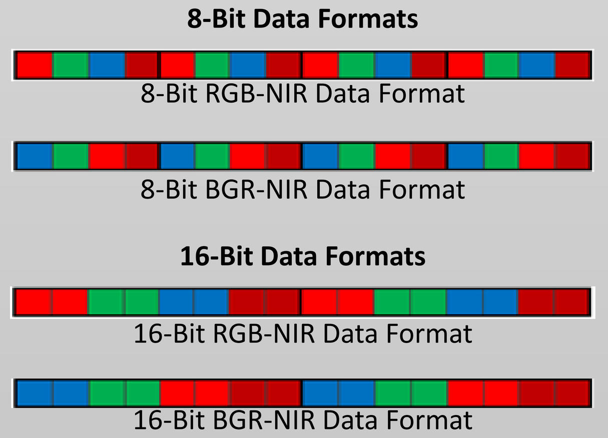
While living plants absorb solar radiation in the process of photosynthesis, leaf cells scatter solar radiation in the near infrared band since this band region is not as useful as other bands like green. Vegetation tends to have higher values in near infrared band, this can be summarized by Normalized Vegetation Index (NDVI) [1]

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

Vegetation Detection with Preprocessing



Algorithm 3: Vegetation Detection Using Pre-processing and Automatic Thresholding.



Modification to NDVI Algorithm : Changing Order of Bands

Conclusions

- Large images expose potential of GPUs.
- GPUs provide significant speed ups for processing of satellite images where images are typically large.
- Use shorter data representation whenever possible to reduce the data transfer time.
- Re-ordering the data in BGR format enables a more efficient memory usage for vegetation detection.

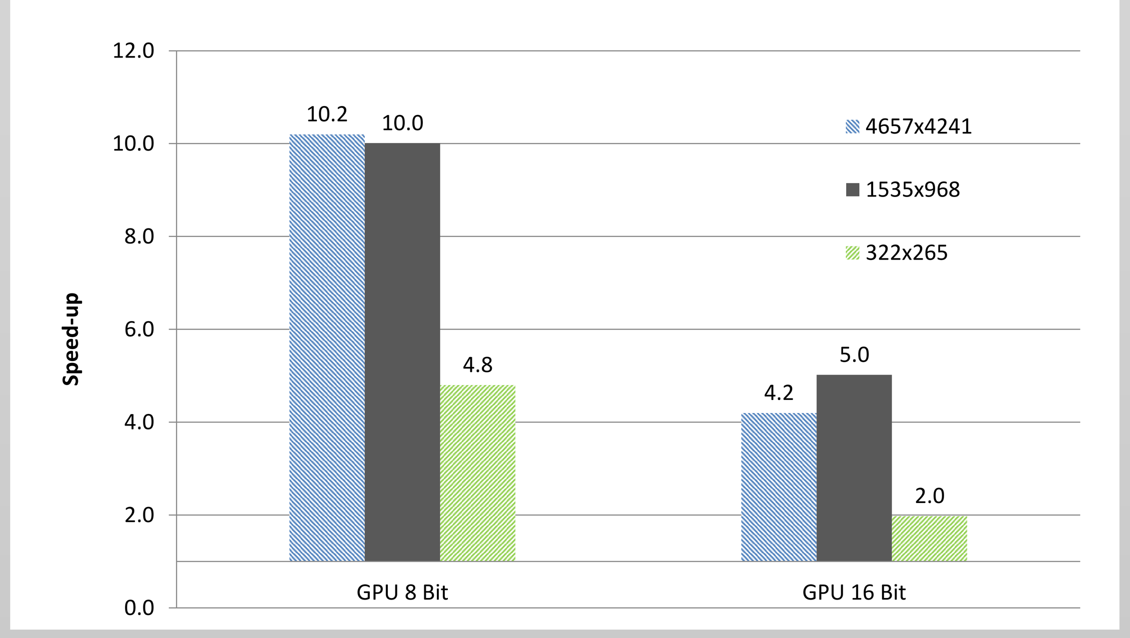
Results of Used Algorithms

Experiments are performed on a PC having Intel Core i7 860 CPU and 8 GB usable RAM. The GPU algorithms are tested with NVIDIA GTX 460.

CPU and GPU Performance Comparison For Complex NDVI Algorithm

	Image Size	Time (ms)	Mpixels/s
GPU 8 Bit Data	322x265	3.04	112.28
	1535x968	15.6	380.99
	4657x4241	163.2	484.08
GPU 16 Bit Data	322x265	5.06	67.45
	1535x968	31.08	191.23
	4657x4241	397.45	198.77
CPU 8 Bit Data OpenMP	322x265	14.62	23.35
	1535x968	156.22	38.05
	4657x4241	1866.28	47.41
CPU 8 Bit Data	322x265	18.42	18.53
	1535x968	311.23	19.10
	4657x4241	4004.91	19.73
CPU 16 Bit Data OpenMP	322x265	10.03	34.03
	1535x968	156.08	38.08
	4657x4241	1688.06	46.80
CPU 16 Bit Data	322x265	14.03	24.33
	1535x968	371.08	16.02
	4657x4241	4467.75	17.68

8-Bit and 16-Bit Speedup Comparisons



NDVI Algorithm Improvements

Further optimization is possible by:

- **Removing Blue and Green bands from preprocessing**
- **Then changing band order on GPU Implementation to have Red and NIR bands next to each other**

Number of Bits	Band Order	Time (ms)	Mpixels/s
8-Bit	RGB-NIR	13.08	455
8-Bit	BGR-NIR	9.57	621
16-Bit	RGB-NIR	20.37	292
16-Bit	BGR-NIR	19.49	305

Effect of Data Size to Performance

Effect Of Image Size

	Image Size	Time (ms)	Mpixels/s
Shadow	322x265	0.38	888
	1535x968	1.73	3440
	4657x4241	22.51	3510
NDVI	322x265	0.38	907
	1535x968	0.73	8094
	4657x4241	7.56	10450
Shadow and NDVI	322x265	0.36	960
	1535x968	1.81	3280
	4657x4241	26.94	2933

Effect Of Memory Transfer To Performance

	Algorithm	Time (ms)	Mpixels/s
GPU 8 Bit Data	Shadow	22.51	3510
	NDVI	7.56	10450
	Shadow + NDVI	26.94	2933
GPU 8 Bit Data w/ Memory Transfers	Shadow	59.88	1319
	NDVI	47.42	1666
	Shadow + NDVI	75.74	1043
CPU 16 Bit Data	Shadow	652.62	121
	NDVI	390.93	202
	Shadow + NDVI	1112.94	71

References

[1] Tucker, C.J., "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation", Remote Sensing of Environment, 8(2),127-150, 1979.