Parallel Multi-Temporal Remote Sensing Image Change Detection on GPU

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2012.5

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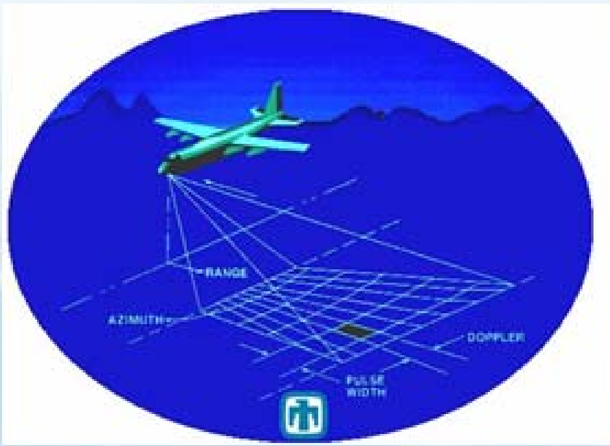
SAR image processing

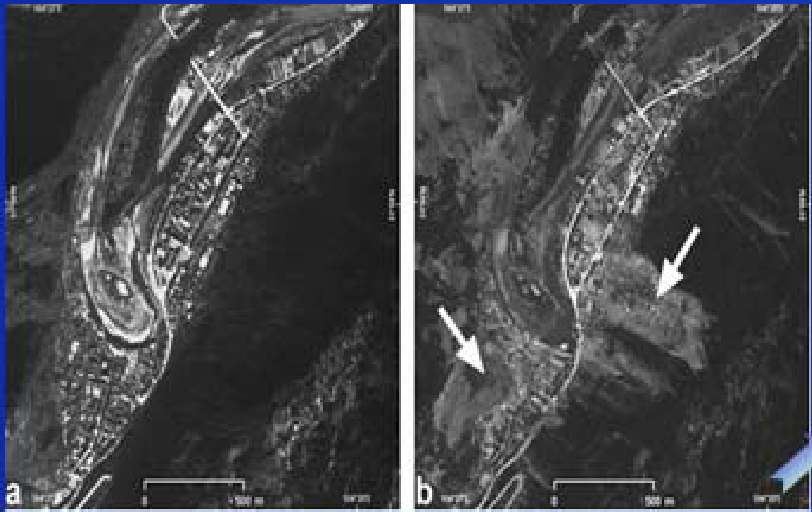
- Synthetic Aperture Radar
- SAR is a radar system which produces high resolution images using signal processing techniques



Change detection

- Detecting regions of change is of widespread interest due to a large number of applications in diverse disciplines such as remote sensing, medical diagnosis, and video surveillance.

Application

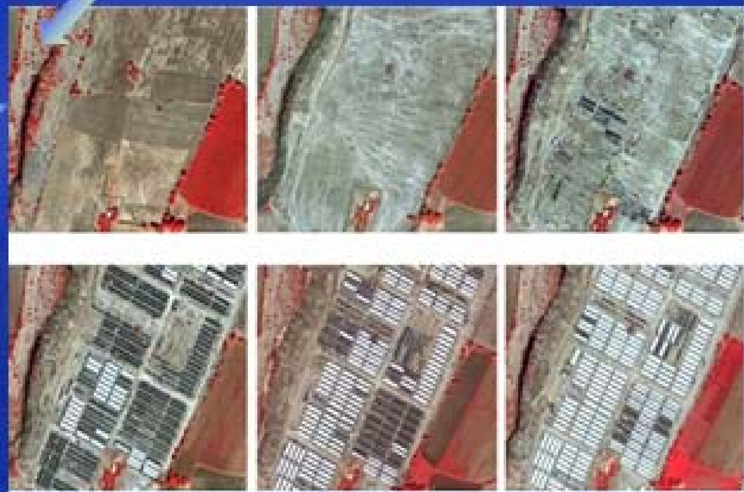


Disaster assessment

Forest surveillance

Change Detection

Military application



City surveillance

motivation

- propose a new change detection algorithm for remote sensing image(Log-FLICM)
- In order to reduce the computational time in image change detection, this project tries to perform the computation in parallel using the general purpose graphics processing unit
- (GPGPU)

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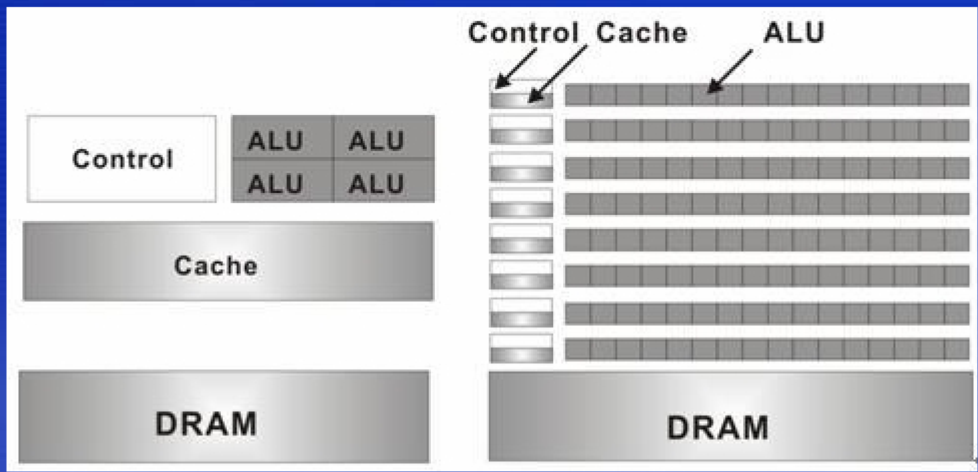
GPGPU

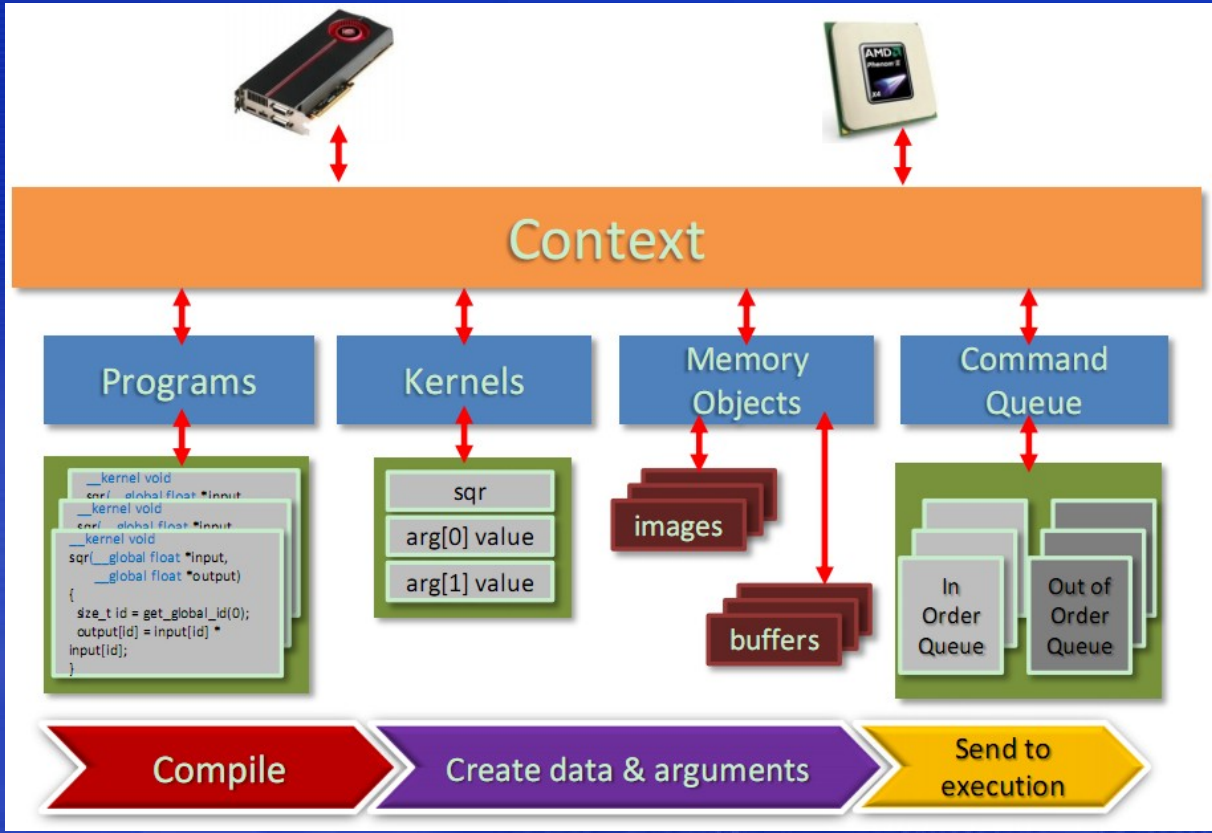


CPU GPU

- GPU is a type of highly parallel, multi-threaded and multi-core processor;
- GPGPU is quite suitable for computing intensive data parallel;
- Jun. 2007, NVIDIA released CUDA;
- Dec. 2008, Khronos Group released OpenCL1.0;
- Aug. 2009, AMD launched ATI Stream SDK v2.0 Beta which supported X86 processor, the OpenCL program models of data parallel and task parallel are included

OpenCL

OpenCL Programming



- support for many processors
- a open standard

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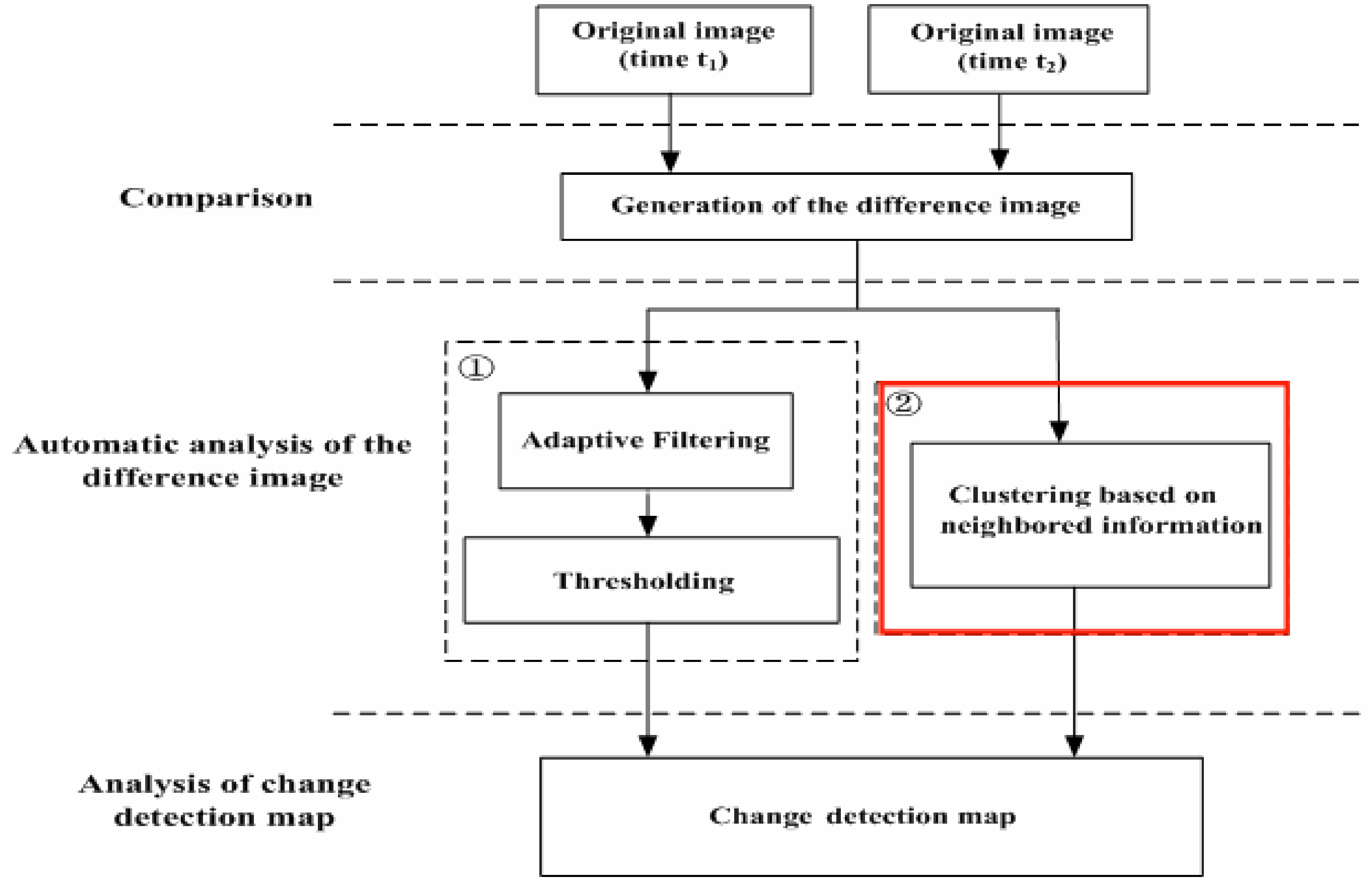
Change detection process



Produce Difference image

log-ratio

$$DI = \log\left(\frac{I_{T1}}{I_{T2}}\right)$$

Clustering

FCM:

$$J_m = \sum_{i=1}^{N} \sum_{k=1}^{c} u_{ki}^{m} (x_i - v_k)^2$$

$$v_k^{(b)} = \frac{\sum_{i=1}^{N} \left(u_{ki}^{(b)}\right)^m x_i}{\sum_{i=1}^{N} \left(u_{ki}^{(b)}\right)}$$

$$u_{ki}^{(b)} = \frac{1}{\sum_{l=1}^{c} \left(\frac{\|x_i - v_k\|^2}{\|x_i - v_l\|^2} \right)^{1/(m-1)}}$$

FLICM

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FLICM framework → Membership Evaluation → Cluster Prototype Updating

FLICM framework

$$G_{ki} = \sum_{\substack{j \in N_i \\ j \neq i}} \frac{1}{d_{ij}+1} (1-u_{kj})^m \left\| x_j - v_k \right\|^2$$

$$J'_m = \sum_{i=1}^{N} \sum_{k=1}^{c} \left[u_{ki}^m \left(\left\| x_i - v_k \right\|^2 + G_{ki} \right) \right]$$

$$\min_{U, \{v_k\}_{k=1}^{c}} \left(J'_m \right), \quad \text{subject to } U \in u$$

Membership Evaluation

$$F_m = \sum_{i=1}^{N} \sum_{k=1}^{c} \left[u_{ki}^m \left(\left\| x_i - v_k \right\|^2 + G_{ki} \right) \right] + \lambda \left(1 - \sum_{k=1}^{c} u_{ki} \right)$$

$$\left[\frac{\delta F_m}{\delta u_{ki}} = m u_{ki}^{m-1} \left(\left\| x_i - v_k \right\|^2 + G_{ki} \right) - \lambda = 0 \right]_{u_{ki} = u_{ki}^*}$$

$$u_{ki}^* = \left[\lambda \big/ m \left(\left\| x_i - v_k \right\|^2 + G_{ki} \right) \right]^{1/m-1}$$

$$\lambda = \frac{m}{\left(\sum_{l=1}^{c} \left(\left\| x_i - v_l \right\|^2 + G_{li} \right)^{1/m-1} \right)^{m-1}}$$

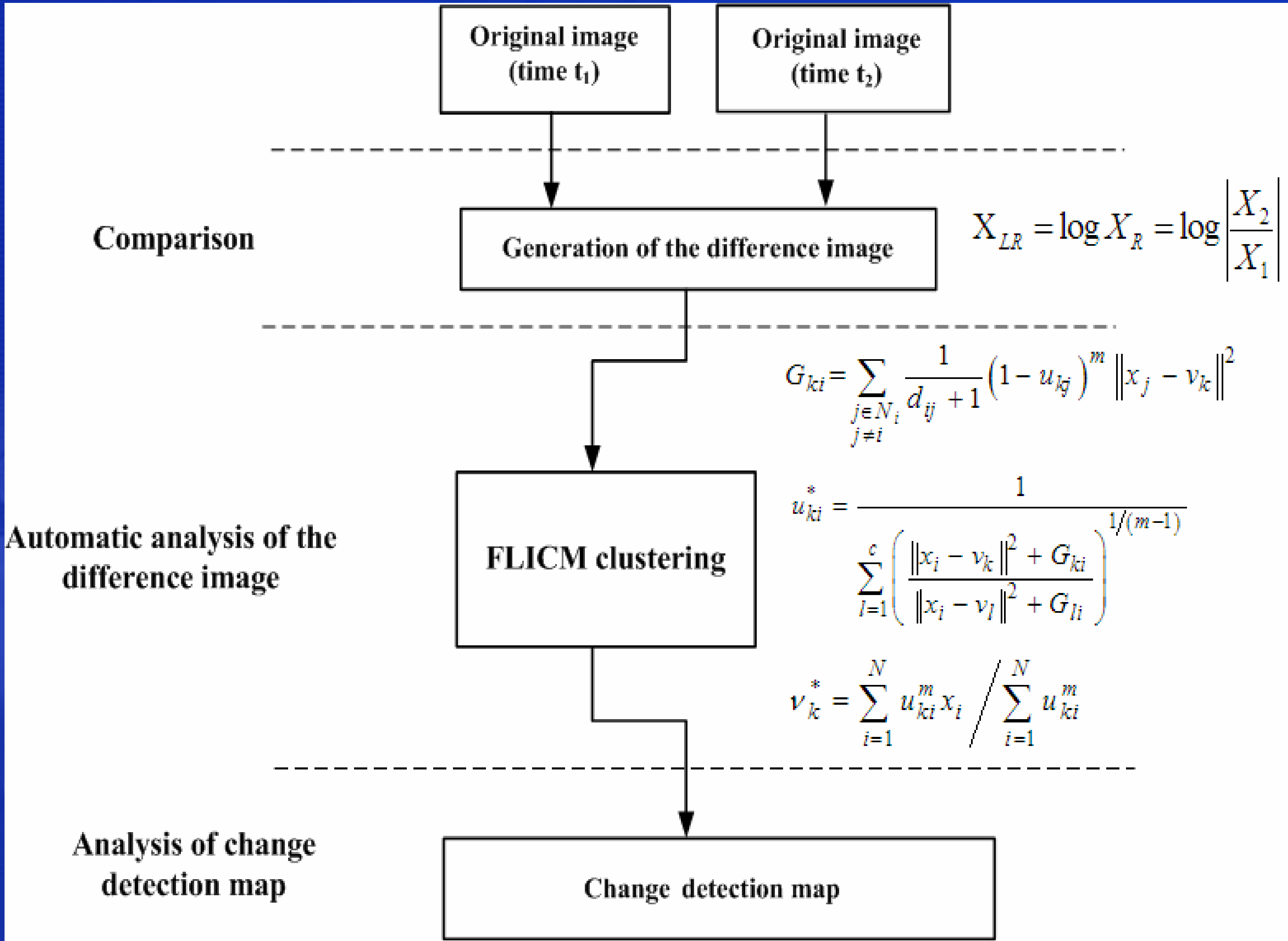
$$u_{ki}^* = \frac{1}{\sum_{l=1}^{c} \left(\frac{\left\| x_i - v_k \right\|^2 + G_{ki}}{\left\| x_i - v_l \right\|^2 + G_{li}} \right)^{1/(m-1)}}$$

Cluster Prototype Updating

$$\left[\sum_{i=1}^{N} u_{ki}^m (x_i - v_k) = 0 \right]_{v_k = v_k^*}$$

$$v_k^* = \sum_{i=1}^{N} u_{ki}^m x_i \Big/ \sum_{i=1}^{N} u_{ki}^m$$

Log-FLICM Algorithm



$$X_{LR} = \log X_R = \log\left|\frac{X_2}{X_1}\right|$$

$$G_{ki} = \sum_{\substack{j \in N_i \\ j \neq i}} \frac{1}{d_{ij}+1}\left(1-u_{kj}\right)^m \left\|x_j - v_k\right\|^2$$

$$u_{ki}^* = \frac{1}{\sum_{l=1}^{c}\left(\frac{\left\|x_i - v_k\right\|^2 + G_{ki}}{\left\|x_i - v_l\right\|^2 + G_{li}}\right)^{1/(m-1)}}$$

$$v_k^* = \sum_{i=1}^{N} u_{ki}^m x_i \Big/ \sum_{i=1}^{N} u_{ki}^m$$

Log-FLICM Algorithm

Step1. Read the two-temporal remote sensing image

Step2. Generate difference image using log-ratio operation at the two-temporal remote sensing image

Step3. Set the number $c = 2$ of the cluster prototypes, fuzzification parameter m and the stopping condition ε.

Step4. Initialize randomly the fuzzy partition matrix $U^{(0)}$.

Step5. Set the loop counter $b = 0$.

Step6. Calculate the cluster prototypes using (5).

Step7. Compute membership values using (6).

Step8. If $\max\left\{U^{(b)} - U^{(b+1)}\right\} < \varepsilon$ then stop, otherwise, set $b = b + 1$ and go to step4.

Step9. Analysis of the change detection map.

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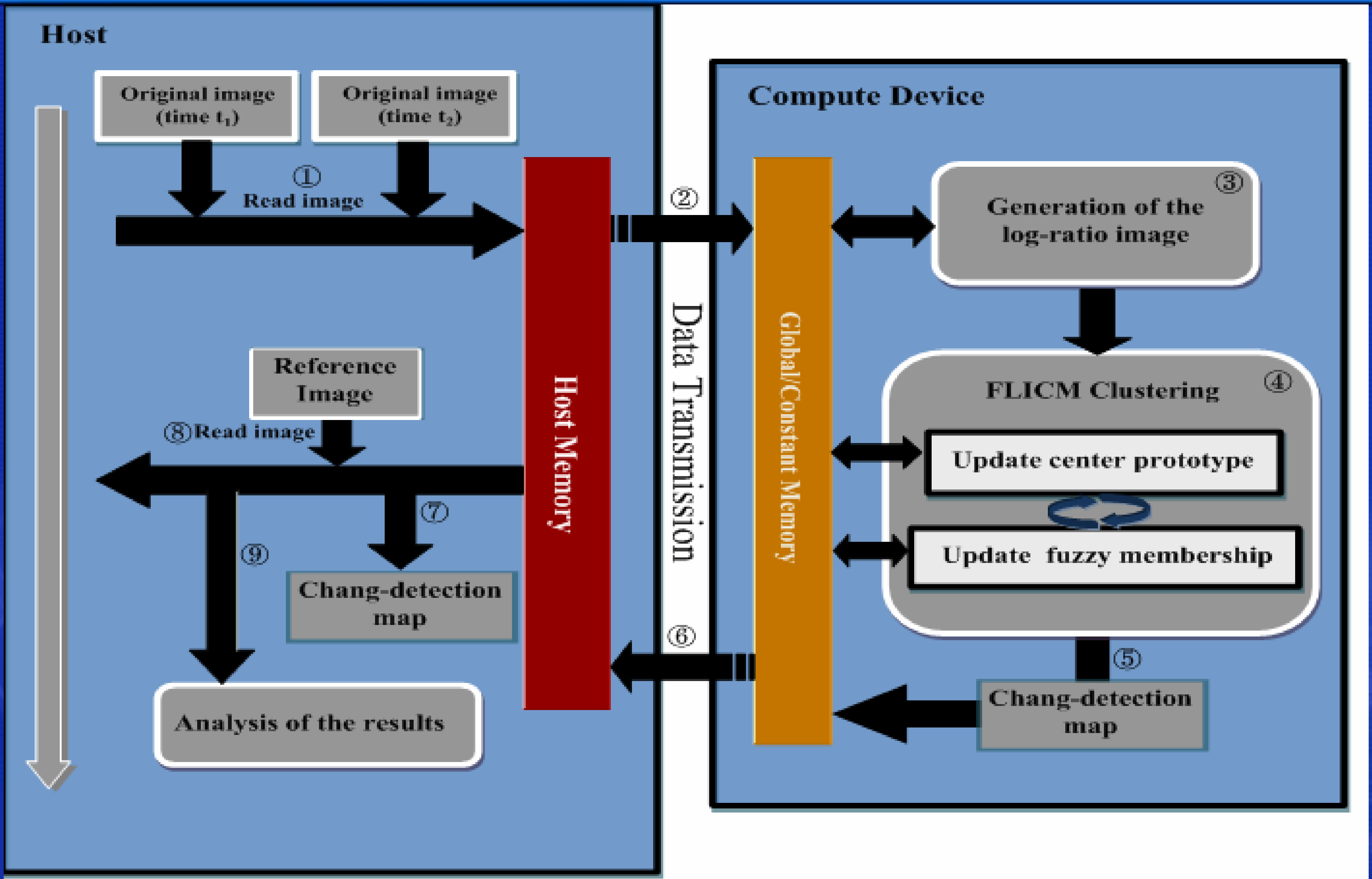
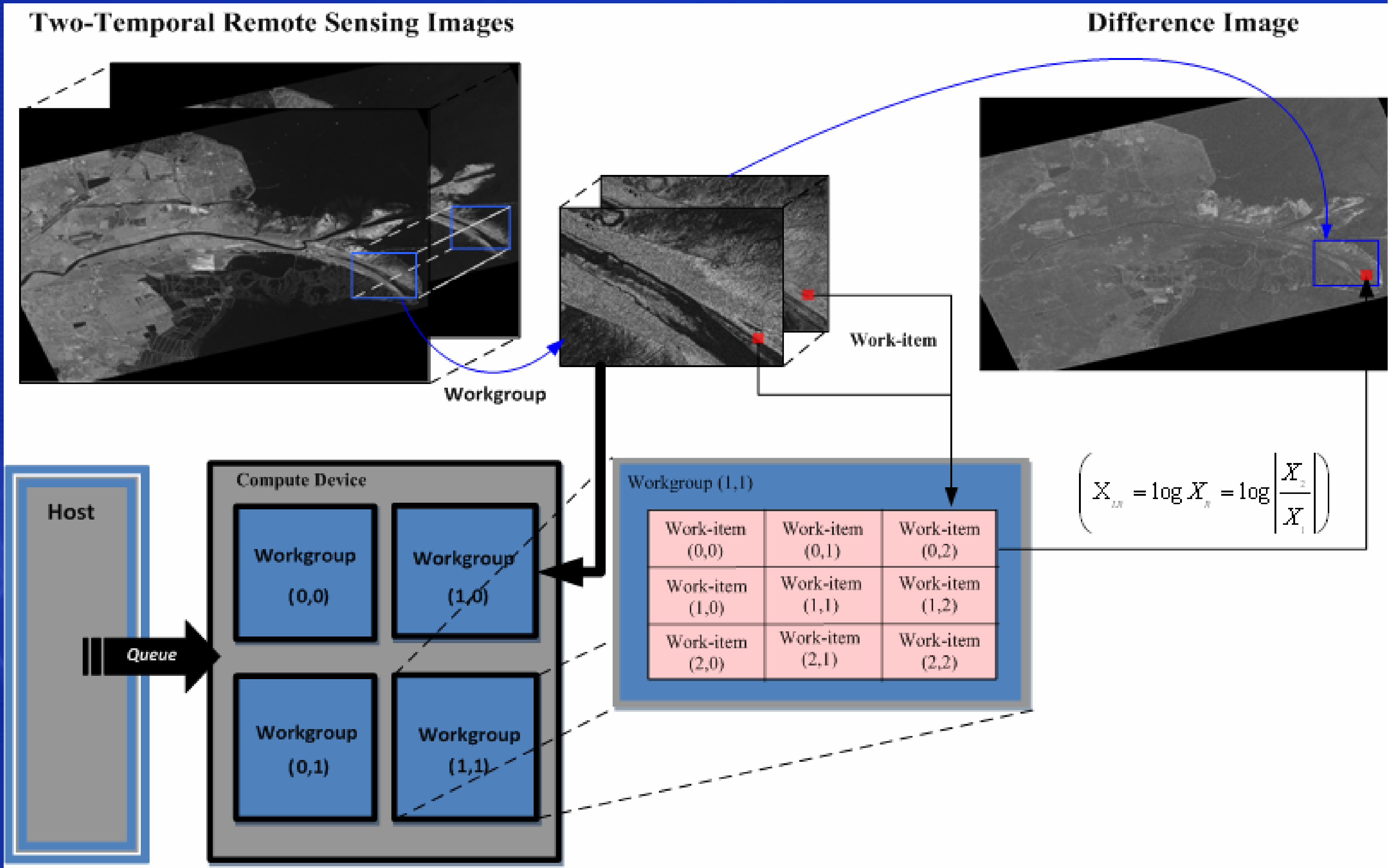
PLog-FLICM


Host
Original image (time t_1)
Original image (time t_2)
① Read image
Host Memory
Reference Image
⑧Read image
⑦
⑨
Chang-detection map
Analysis of the results
② Data Transmission ⑥
Compute Device
Global/Constant Memory
Generation of the log-ratio image ③
FLICM Clustering ④
Update center prototype
Update fuzzy membership
⑤
Chang-detection map

The parallel generation of difference image



- As shown in the figure , the diagram of parallel generation of difference image on GPU, the two temporal remote sensing images can be divided into many Workgroups, and every pixel of the image can correspond to the Work-item at each Workgroup. The work-item at each Workgroup produces the difference base on the formula

$$\left(\mathrm{X}_{LR} = \log X_R = \log \frac{X_2}{X_1} \right)$$

to generate the difference image.

The normalization of difference image

In order to clustering the difference image better at the next step, we will normalize the difference image. In the process of normalization, it will involve the maximum and minimum calculation on difference matrix. So we employ the reduction technique to deal with it.

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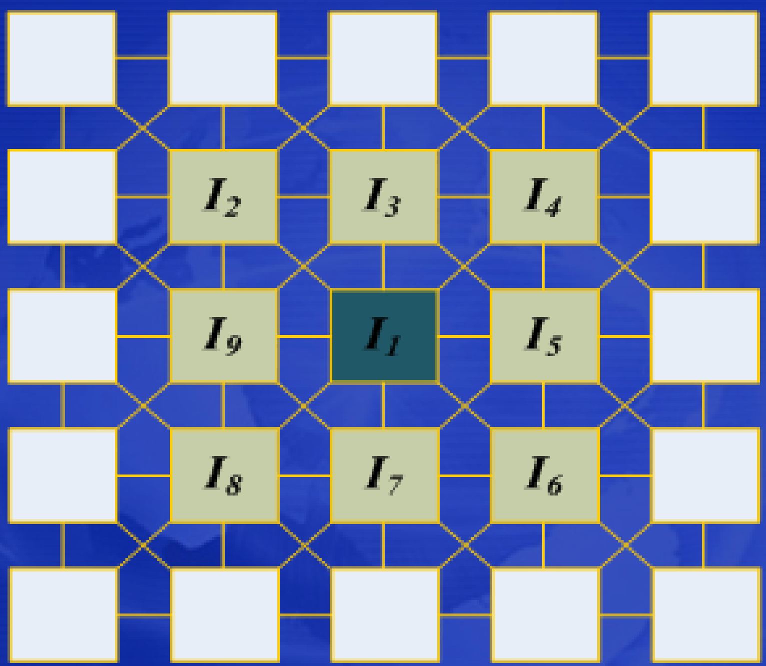
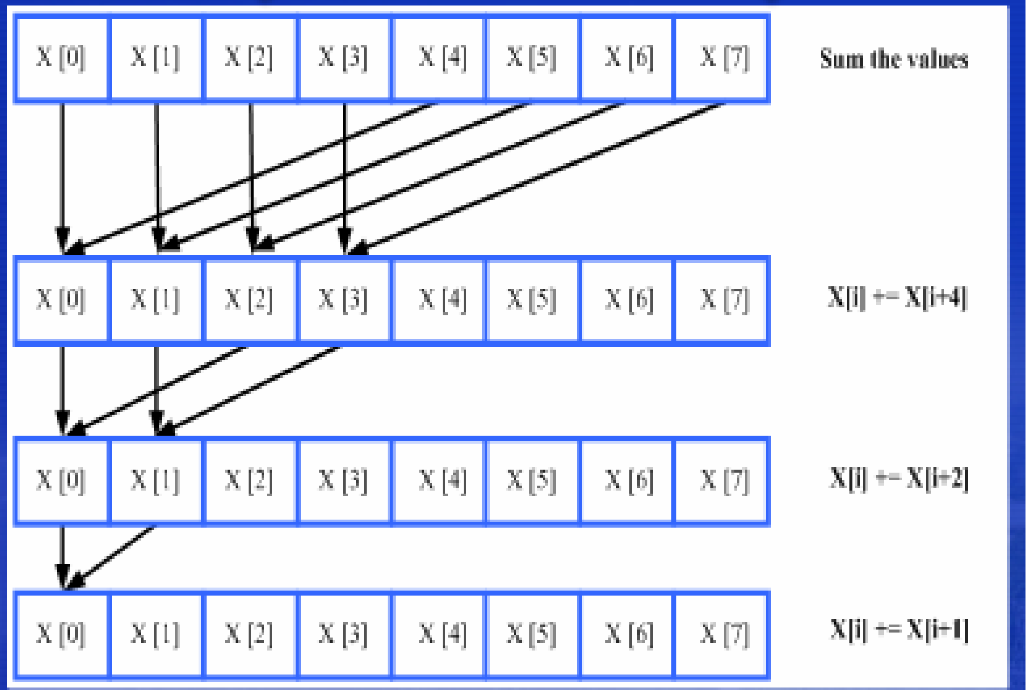
FLICM algorithm clustering

$$G_{ki}=\sum_{\substack{j\in N_i\\ j\neq i}}\frac{1}{d_{ij}+1}\left(1-u_{kj}\right)^m\left\|x_j-v_k\right\|^2$$

Membership Evaluation

Cluster Prototype Updating





relationship diagram of neighborhood information

reduction for sum

Contents

Experimental Environment

Host		Device	
Product Name	HP xw9400 workstation	Product Name	AMD Radeon™ HD 6870
OS	Windows XP Pro. x64 Edition OS China	Engine Speed	900MHz
CPU	4× Dual-Core AMD Opteron 2220 2.80GHz	Processing Elements	1120
Memory	32GB	Memory	1GB GDDR5
		Memory Bandwidths	134.4 GB/s
		PCI	PCI Express® 2.1 x16

AMD Accelerated Parallel Processing (APP) SDK v2 which supports OpenCL 1.1；

Programming Environment： Microsoft Visual Studio 2010；

Serial programming ： Host；

Parallel programming ： Host + Device；

Performance Evaluation

false negatives (FN): The number of pixels that are detected as changed area in reference but detected as unchanged area in the result;

false positives (FP): The number of pixels that detected as unchanged area in reference image but detected as changed area in result;

overall error (OE):: The sum of FN and FP;

percentage correct classification (PCC), it can be defined by:

$$PCC=((TP+TN)/(TP+FP+TN+FN))$$

Here TP is short for true positives, which is the number of pixels that are detected as the changed area in both the reference image and the result. TN is short for true negatives, which is the number of pixels that are detected as the unchanged area in both the reference image and the result.

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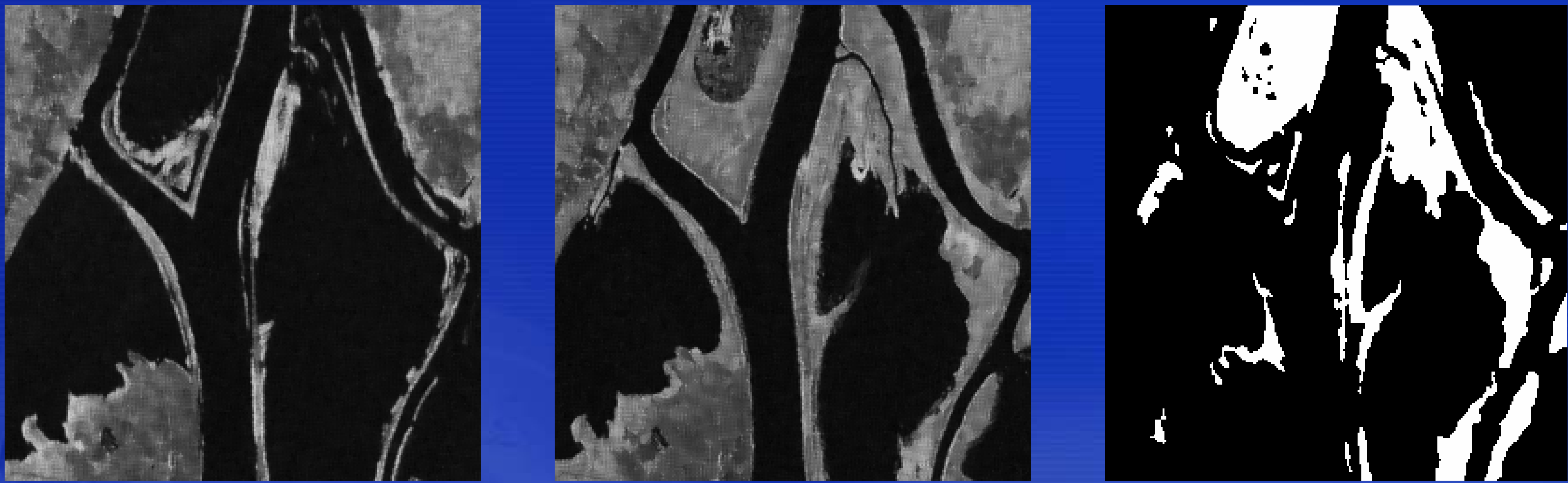
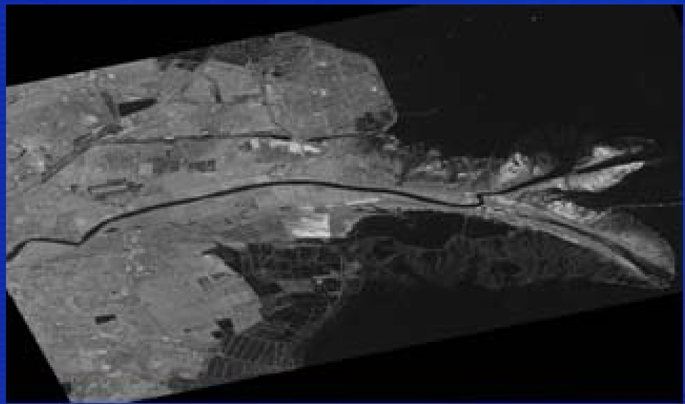
Datasets-- Ottawa



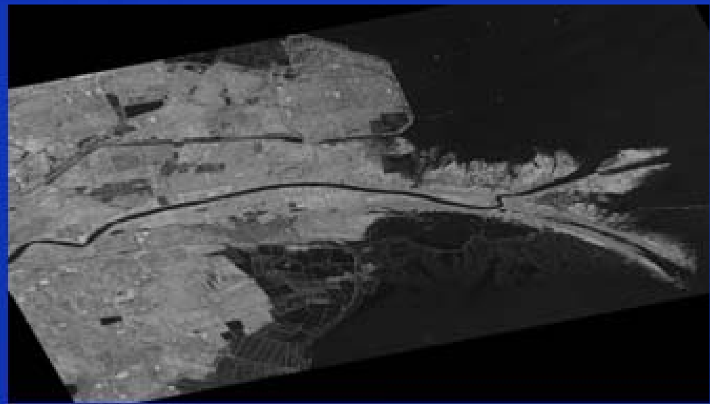
(a) (b) (c)

(a) acquired in July, 1997. (b) acquired in August, 1997. (c) ground truth image.

Datasets-- Yellow River Estuary



(a) acquired in June, 2008.



(b) acquired in June, 2009.

TEST-Dataset	Group (image t1 and t2)	Image size (height wide)	Capacity
Yellow River Estuary	Group1	512 512	257KB
	Group2	1024 1024	1MB
	Group3	2048 2048	4MB
	Group4	4096 4096	16MB

Change detection maps of the Ottawa

(a)

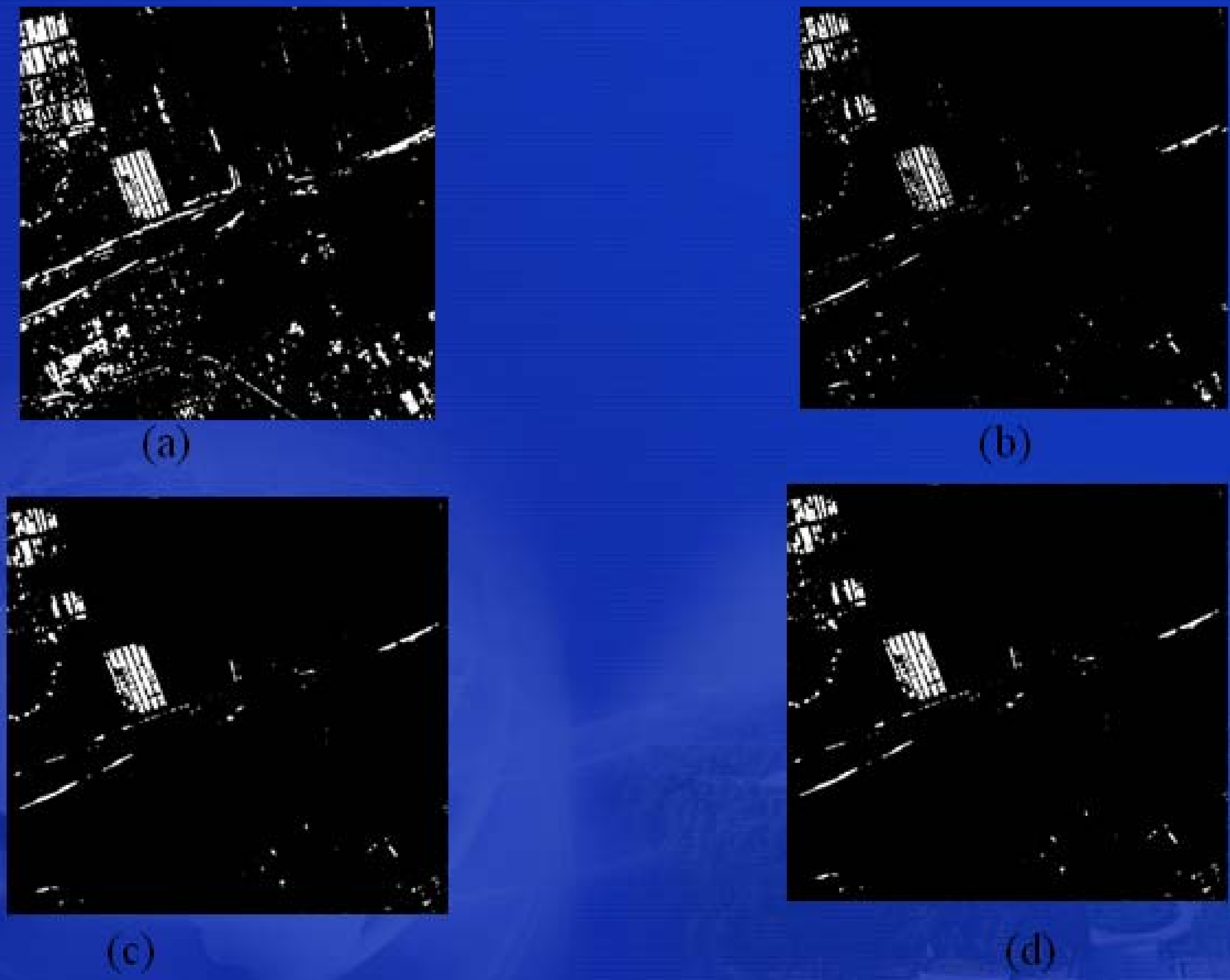
(b)

(c)

(d)

(a) Log-KI (b) Log-GGKI (c) Log-FLICM (d) PLog-FLICM

Experimental Result



(a) Log-KI (b) Log-GGKI (c) Log-FLICM, (d) PLog-FLICM

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Experimental Result

Comparison of the change detection results

Dataset	Methods	FP	FN	OE	PCC
Ottawa	Log-KI	641	1442	2083	96.72%
	Log-GGKI	592	1477	2069	96.73%
	Log-FLICM	52	1542	1594	97.47%
	PLog-FLICM	56	1540	1596	97.46%

Speedup

Iterations = 1

Dataset	Group (image t1 and t2	CPU(/s)	GPU(/s)	Speedup
Yellow River Estuary	Group1 (512 512)	2.984	0.047	63.49
	Group2 (1024 1024)	12.000	0.11	109.09
	Group3 (2048 2048)	48.047	0.453	106.06
	Group4 (4096 4096)	191.454	2.422	79.05

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Speedup

Iterations = 10

Dataset	Group (image t1 and t2)	CPU(/s)	GPU(/s)	Speedup
Yellow River Estuary	Group1 (512 512)	**72.906**	**0.516**	**141.29**
	Group2 (1024 1024)	**293.406**	**1.875**	**156.48**
	Group3 (2048 2048)	**1176.204**	**8.828**	**133.24**
	Group4 (4096 4096)	**4691.375**	**49**	**95.74**

Conclusion

- Propose a new change detection algorithm in remote sensing image and its parallel version on GPU;
- The design flow and implement details on GPU are present about PLog-FLICM;
- The parallel design on producing difference image and FLICM clustering is implemented;
- The proposed algorithm is very effective;
- Gain good accelerating performance on Yellow River Estuary dataset.

Thank you!

Q&A?