Object Recognition by Selective Algorithm with CUDA Implementation

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Introduction

- **In factory automation, robot arms replace human-manual assembly.**
- **To pick the specific object, we should know the location of the object.**
- **To know locations of objects, pattern recognition is essential.**
- **It is not only for factory automation, but can be applied to the most of automations.**

Introduction

- ***Ring Projection Transforms (RPT)*** **can be a method to find the location.**
- **RPT is rotation-invariant, but very slow on general CPU (ex. Intel Core-i7 series).**
- **For example, RPT consumes about 2500ms for 99x99 target image on 640x480 scene.**
- **Therefore, processing time is one of major issue to be used in practice.**

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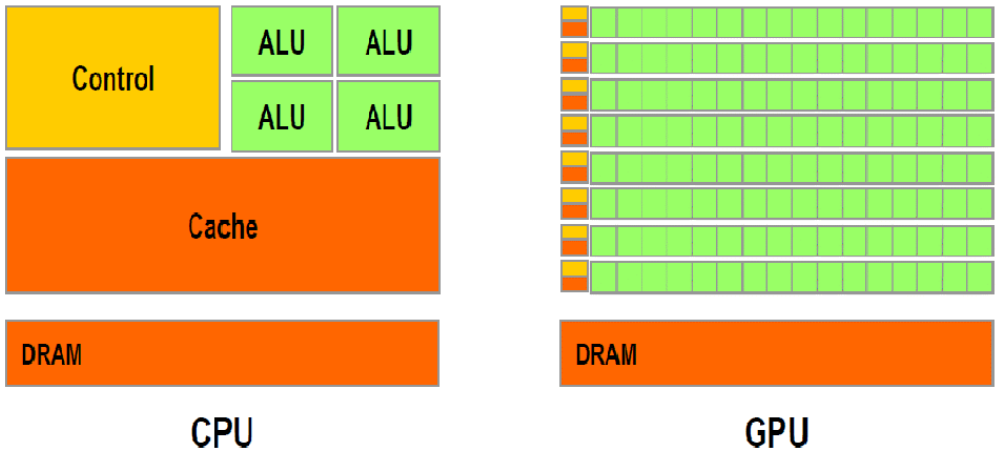
Related Work

1. **What is GPGPU?**
   1) **Using GPU at general computing**
      - **GPGPU is abbreviation of 'General-Purpose computing on Graphics Processing Units'**
   2) **Why?**
      - **Unlike CPU, GPU has lots of APU, smaller cache, and smaller control units.**
      - **It means that GPU is good to calculate large data, but poor to control branches.**



Related Work

2. What is CUDA?

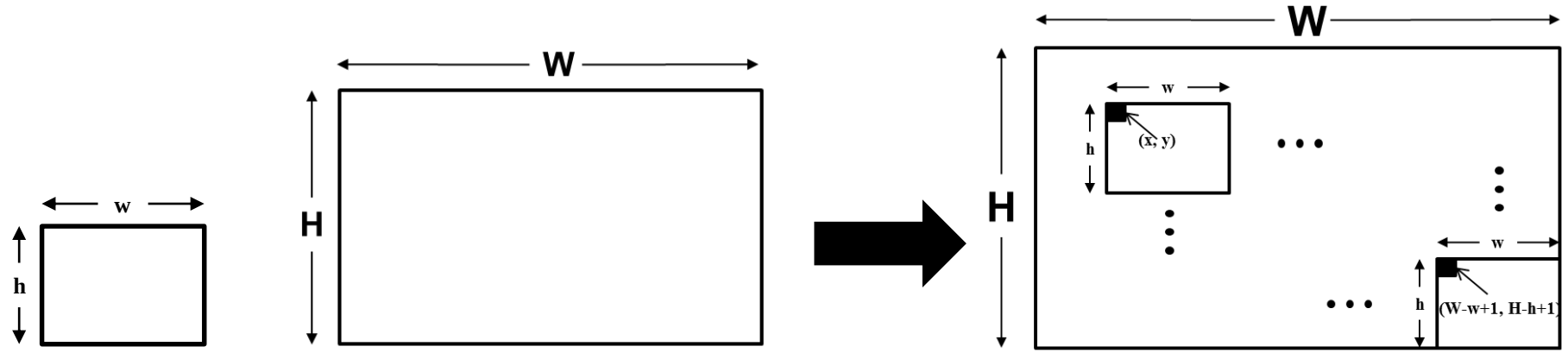
1) A kind of GPGPU
2) Abbreviation of “Compute Unified Device Architecture”
3) Developed by nVIDIA

Related Work

3. What is RPT in detail?

1) A kind of block based matching

- To find object on the scene, slide object over the scene. Whenever you slide, calculate the degree of similarity.
- If there is only 1 object in the scene, then the location of highest degree indicate the location of object.



<Object> <Scene> <Scheme>

Related Work

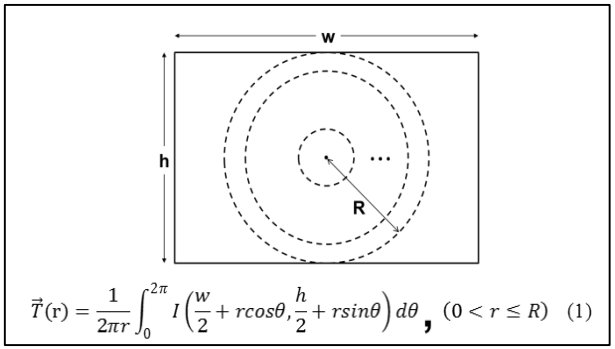
3. What is RPT in detail?

2) Rotation-invariant matching

Step 1: To calculate similarity, extract vector T(r) from object image. I(x, y) is the value of pixel at (x, y) on the object image.

Step 2: extract vector $S_{(x,y)}(r)$ from scene image according to equation (2).

Step 3: calculate 'Normalized Cross-Correlation(=NCC(x, y))' between T(r) and $S_{(x,y)}(r)$.



$$\vec{T}(\mathrm{r}) = \frac{1}{2\pi r}\int_0^{2\pi} I\left(\frac{w}{2} + r\cos\theta, \frac{h}{2} + r\sin\theta\right) d\theta \text{ , } (0 < r \le R) \quad (1)$$

$$\overrightarrow{S_{(x,y)}}(r) = \frac{1}{2\pi r}\int_0^{2\pi} I'\left(x + \frac{w}{2} + r\cos\theta, y + \frac{h}{2} + r\sin\theta\right) d\theta \text{ , } \begin{pmatrix} 0 \le x \le W-w+1 \\ 0 \le y \le H-h+1 \\ 0 < r \le R \end{pmatrix} \quad (2)$$

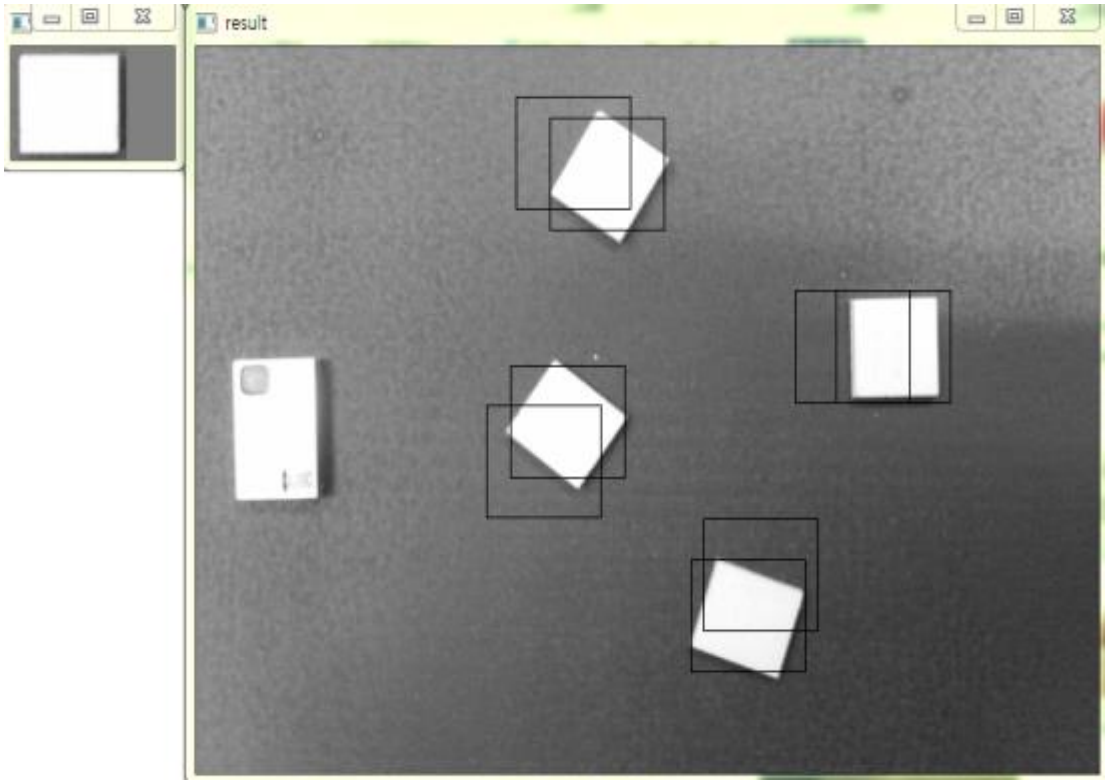
$$\mathrm{O}(\mathrm{x},\mathrm{y}) = \mathrm{NCC}(\vec{T},\ \vec{S}_{(x,y)}) = \frac{Co-variance(\vec{T},\vec{S}_{(x,y)})}{(R-1)\sigma(\vec{T})\sigma(\vec{S}_{(x,y)})} \quad (3)$$

Related Work

3. What is RPT in detail?

3) Unavailable for plain pattern object

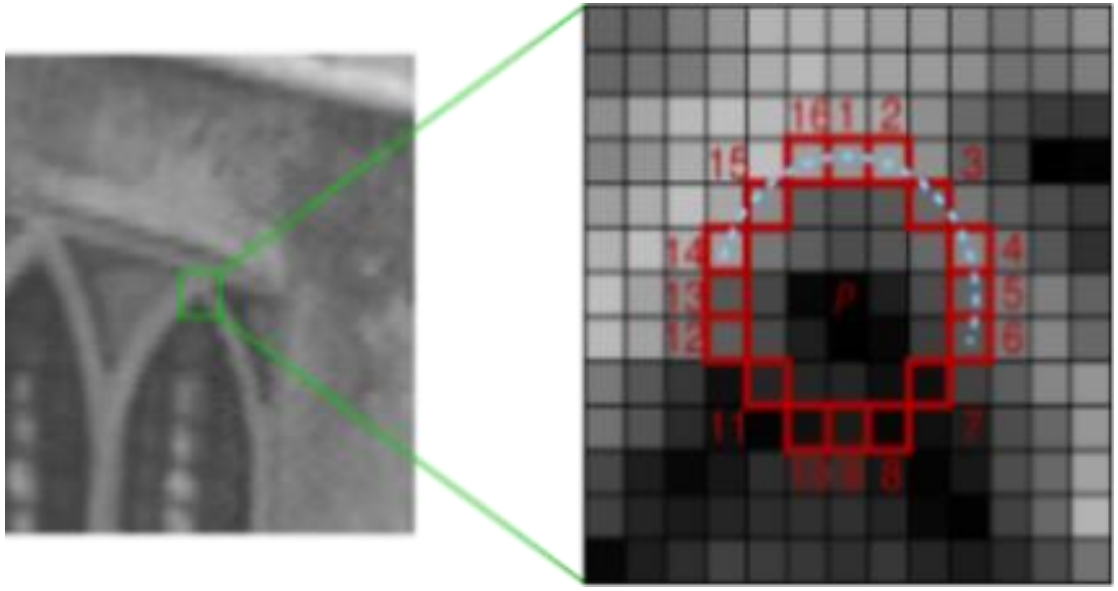
- If object has plain pattern, then RPT will find wrong point which is located in nearby object.



Related Work

4. What is ‘FAST’ in detail?

1) Abbreviation of ‘Features from Accelerated Segment Test’
2) One of method for detect corner points



Related Work

5. What is ‘Contour Matching’ in detail?

1) Method to find object by only contour set.
2) Since it uses only contour, it is suitable for plain pattern object which is not common object.
3) It is calculated by moments of image.

$$m_{ji} = \sum_{x,y} (I(x,y) \cdot x^j y^i)$$

$$\mu_{ji} = \sum_{x,y} (I(x,y) \cdot (x-\bar{x})^j (y-\bar{y})^i)$$

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{01}}{m_{00}}$$

$$\eta_{ji} = \frac{\mu_{ji}}{m_{00}^{(1+(i+j)/2)}}$$

$$hu(0) = \eta_{20} + \eta_{02}$$

$$hu(1) = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$$

$$hu(2) = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

$$hu(3) = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$hu(4) = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

$$hu(5) = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03})$$

$$hu(6) = (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] - (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

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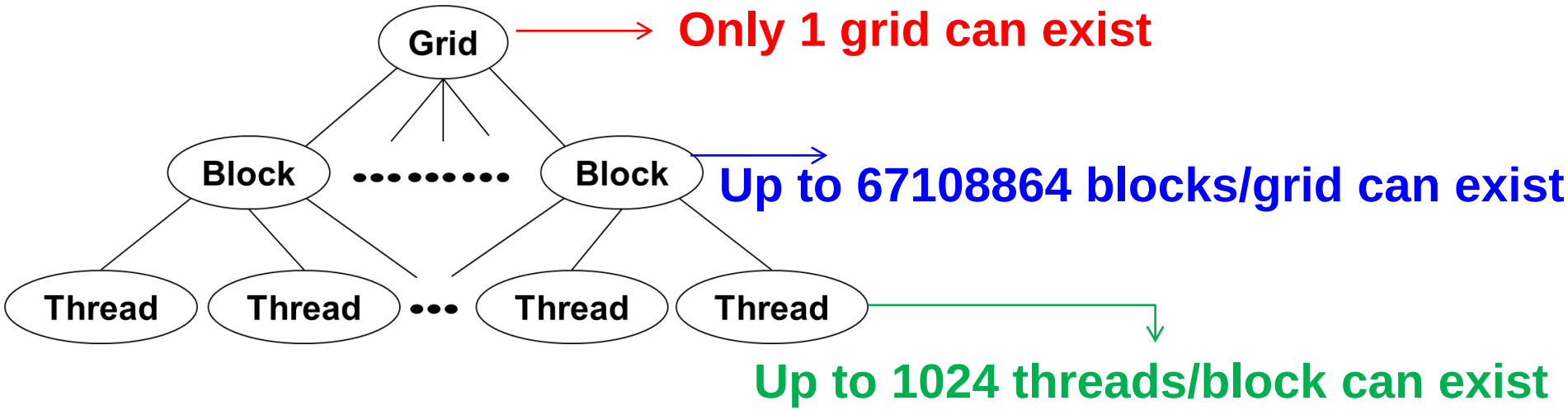
Proposed Method

1. Thread allocation

1) CUDA provides logically hierarchical structure with grid, block, and thread



Proposed Method

1. **Thread allocation**
   2) **After calculating RPT, we will get (W-w+1)(H-h+1) values of result**
   3) **Therefore, to assign 1 thread/value, we will allocate an in Equation (4).**

$$block(x, y) = \left(\frac{(W-w+1)+thread.x-1}{thread.x}, \frac{(H-h+1)+thread.y-1}{thread.y}\right) \quad (4)$$

Proposed Method

2. Strategy of using memory

1) CUDA provides several kinds of memory.
   - Global memory : Slowest but largest.
   - Shared memory : Fastest but smallest.
   - Texture memory : L1-cached memory.
   - Constant memory : L1-cached and broad casting.
2) In case of constant memory, we can achieve 16 times speed for accessing memory.
3) To maximize this advantage, we will store T(r) in constant memory because whole threads will load T(r) at the same time.

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Experimental Result

- **The main purpose is to improve speed of RPT algorithm.**
- **Therefore, we measure time for calculating.**
- **The experiments were conducted on a PC with running Windows 7 64bit, 16 GB RAM, Intel Core i5-4670 3.4GHz processor and GeForce GTX 770. The graphics card has 2GB RAM on board.**
- **The test image set contains a scene image with size 640x480 and template image with size 99x99.**

Experimental Result

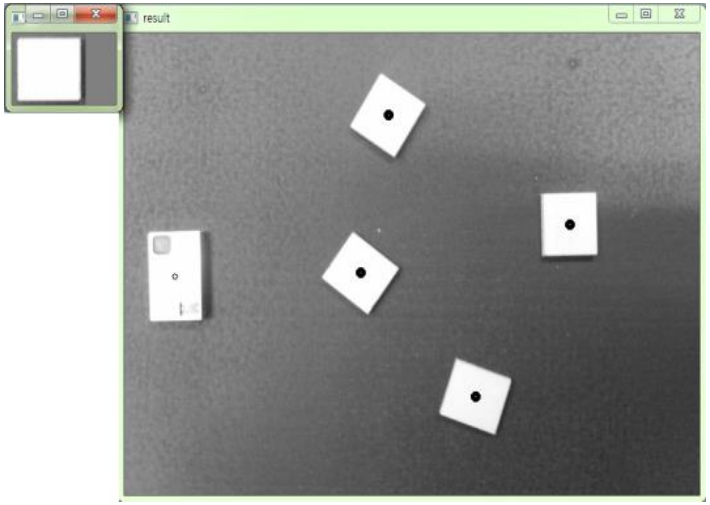
<Object image> **<Scene image>** **<Result image>**

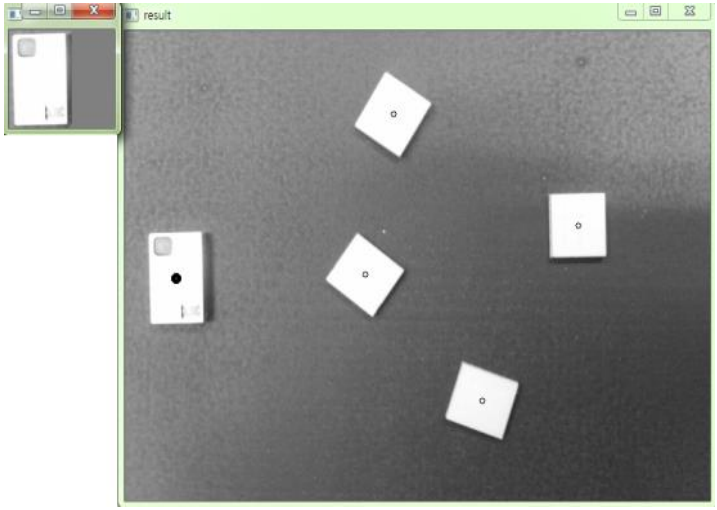
TIME CONSUMPTION FOR PROCESS

Without CUDA	With CUDA	Degree of improvement
2645.00[ms]	75.37[ms]	x35.1

Experimental Result

- **Case of Plain Pattern Object.**





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Conclusion

- **Our proposed method provides high computing power and applicability for general use. Thus, we can make this algorithm available option for other automation systems.**

- **Also, our proposed method can be a suitable solution to shorten processing time for pattern recognition.**

- **Furthermore, we also can apply our method not only to pattern recognition but also to other computing problems.**

Thank You