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FPGA implementation of Efficient and High Speed Template Matching Module

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Abstract— Template Matching is a digital image processing technique used in classifying objects .Due to changing intensity and template size the computational complexity increases. In our project we have simplified the original normalized cross-correlation(NCC) algorithm and designed a parallel processing pipelined architecture circuit to improve the computational speed and accuracy .This template matching module can be used in all types of vision applications, pattern recognition and elastic matching.

Index Terms— Image processing, mean, Normalized cross-correlation, template matching.

I. INTRODUCTION

Inspection is the main criteria in quality control of products in manufacturing industries. The key agenda of inspection is classifying objects and locate the object under inspection. The normalized cross-correlation is one of the most popular methods for image matching. While fast implementations of the algorithm itself are available in standard mathematical toolboxes, such as Matlab, there still are ways to get significant speed-up for many applications.

For many years, vision researchers have believed that the central problem of matching was one of computational cost. To reduce the cost of matching, researchers have sought to perform matching at the highest possible level of abstraction. Most techniques involved constructing a hierarchy of increasingly abstract image descriptions, matching at the most abstract level, and then propagating correspondences back down the hierarchy to determine association of parts.

The various matching methods that have been proposed can be distinguished by what type of features are used [12]. At the one end there are pixel-based methods, which models directly to (filtered) image pixels. At the other end there are symbolic matching methods which operate on a few high-level features (e.g. parts of objects and their relations) and apply graph matching methods to establish correspondence.

Template matching is one of the simplest image detection methods. The idea is to slide an image template (binary shapes, or gray level patterns) over the image at hand { a 2D search { to see if an image object matching the template can be found somewhere in the image. The image template can be stored in the library as a 2D array t(i; j) (i = -m/2…m/2; j = -n/2….n/2), where m * n is the size of the object.

- Template Matching techniques compare portions of images against one another.
- Sample image may be used to recognize similar objects in source image.
- If standard deviation of the template image compared to the source image is small enough, template matching may be used.
- Templates are most often used to identify printed characters, numbers, and other small, simple objects.
- In signal processing, **cross-correlation** is a measure of similarity of two waveforms as a function of a time-lag applied to one of them. This is also known as a sliding dot product or sliding inner-product. It is commonly used for searching a long-signal for a shorter, known feature. It also has applications in pattern recognition, single particle analysis and the ,electron tomographic averaging, cryptanalysis, and neurophysiology.

Correlation is widely used as an effective similarity measure in matching tasks. However, traditional correlation based matching methods are limited to the short baseline case. In this paper we propose a new correlation based method for matching two images with large camera motion.. Image matching plays an important role in many applications A lot of matching algorithms have been proposed in the literature [8,10]. Matching two uncalibrated images with large camera motion such as significant rotation and scale changes still remains a difficult problem. One effective strategy is using feature matching approach, which extracts salient features such as corners in the two images and then establishes reliable feature correspondences.Normalized cross-correlation has found application in abroad range of computer vision tasks such as stereo vision, motion tracking, image mosaicking , etc. [2].Normalized cross correlation is the simplest but effective method as a similarity measure, which is invariant to linear brightness and contrast variations[8]. Its easy hardware implementation makes it useful for real-time applications. There have been some image matching methods based on normalized cross-correlation [6,7]. However, these methods cannot perform well when there are significant rotation and scale changes between the two images. This is due to the limitation that normalized cross-correlation is sensitive to rotation and scale changes. Therefore, traditional correlation based matching methods are not robust against rotation and scale changes. Template matching has been a fundamental technique in machine vision for detecting objects in complex images.

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The main limitations of traditional pattern matching methods are that an enormous number of templates must be matched against an image field to account for changes in rotation of reference templates, and the measure of similarity must be carried out in a pixel-by-pixel manner. In this paper, we have tackled the problem of pattern matching using the wavelet decomposition and ring-projection representation. The proposed method significantly reduces the number of search pixels by using the composite detail subimage at a low resolution level. The computation of correlation coefficients is only carried out for those high energy-valued pixels in the composite detail subimage[5].

In practice, the template matching spends 224ms under the support of the largest image size. However, neither search window size nor processing speed is sufficient for real time applications; for instance, a surveillance system needs a search window of size 640x480 with 30 frame-per-second (FPS) performance. To cope with larger template size, a scalable architecture was proposed by Gupta [9]. The circuit can be expanded by cascading chips. Our module implemented a simplified NCC algorithm. It also adopts sub-sampling and two-stage matching techniques. In the two-stage matching we take advantage of the calculation result of first stage to automatically populate the search map for second stage. The simplified NCC algorithm is implemented into an NCC computation circuit which utilizes pipelined architecture and parallel computation. The proposed real-time matching module can perform real-time matching for template sizes ranging from 64x64 pixels.

II. METHODOLOGY

A. Method

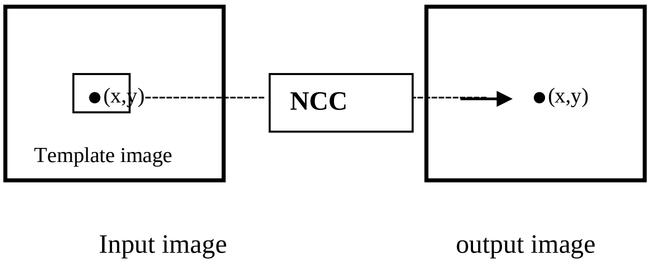

Fig.1 Overview of the template matching module.

The matching process moves the template image to all possible positions in a larger source image and computes a numerical index that indicates how well the template matches the image in that position. Match is done on a pixel-by-pixel basis.

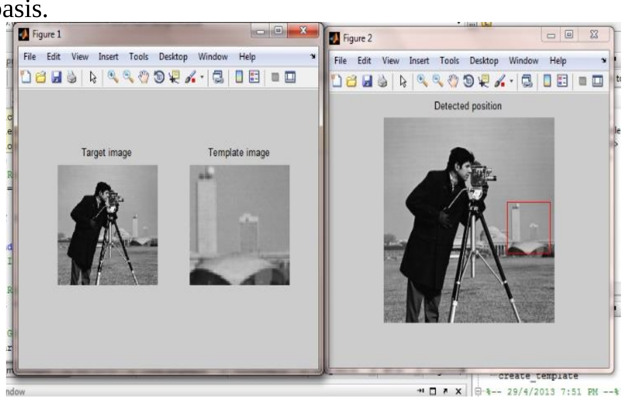

Fig 2: Template Matching Output Result

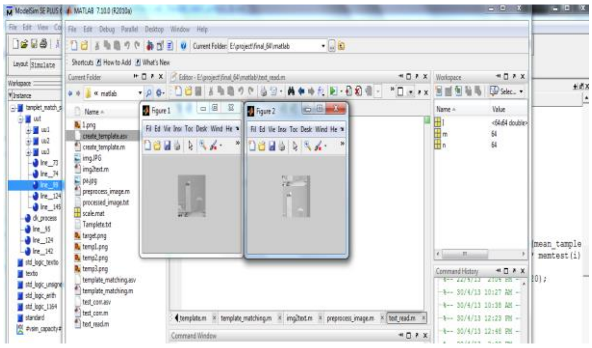

Fig 3:Detected template image

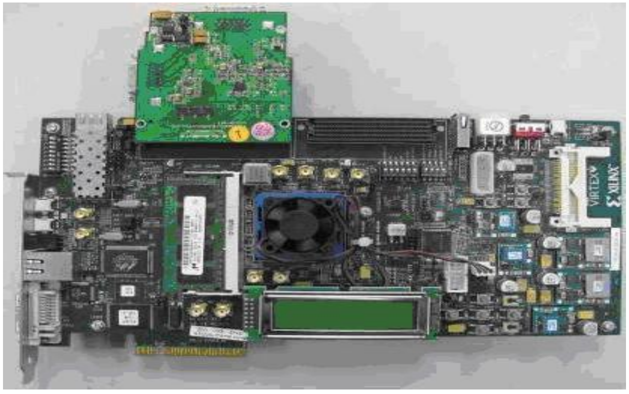

Fig 4 The real time template matching module

B .Normalized Cross Correlation

The existence of low cost correlation hardware makes cross-correlation a very attractive operation. The crosscorrelation, provided that both the template and the Image neighborhood are suitably normalized. The most direct normalisation is to divide each inner product by the square root of the energy of the template and the neighborhood. Mathematically, this can be expressed as

$$\frac{1}{N}\frac{\sum_{i=1}^{N}(s_i - s')(t_i - t')}{\sum\sqrt{\sum(s't')^2}} \qquad (1)$$

Where s' and t 'are the means of samples s_i and t_i , respectively. The Mean is defined as:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (2)$$

TABLE I SPECIFICATION OF NCC CIRCUIT

Template image size	Min. template size	Max. template size
	3×3	256×256
Min. search window size	64×64	256×256
Max. search window size	640×480	
Computation time	‹15ms	

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TABLE II SPECIFICATION OF FPGA PLATFORM

Speed	100MHz
Target platform	Xilinx SpartanIII

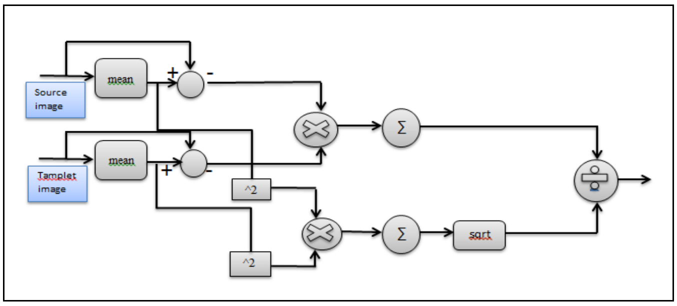

FIG 5.BLOCK DIAGRAM OF NCC CIRCUIT

The Fig 5 shows the procedure how the actual template matching is been performed. Correlation is a measure of the degree to which two variables agree, not necessary in actual value but in general behavior. The two variables are the corresponding pixel values in two images, template and source. The mean operation is been performed on the source and the template image that is the pixel values are taken for evaluation. Based on the Normalized cross correlation equation (1) the calculation is been done. In the final stage the divider operator is been used to perform the comparsion of both source and the template image if the template matches in the source image then in the output the template image will be displayed otherwise the 0's that is the black spot will be recognized in the output. Since only the operators have been used hence the usage of area on the FPGA is commandingly reduced which result in high computation speed that is <15ms for any size of search window and template image. To improve the throughput of circuit operation and reach the real-time requirement, the NCC circuit adopts full pipelined design that makes front-end and back-end circuits compute simultaneously. Moreover, the RAM controller employs a circular buffer structure to reduce RAM usage.

III. EXPERIMENTAL RESULTS

The performance of the preferred NCC circuit is been executed in the PC which is been equipped with Intel Core i3 Processor@3GHz and 6GB RAM.

The TABLE II specifies which platform is been used for the FPGA implementation with a speed of 100MHz.

The TABLE III shows the performance of the NCC Circuit in FPGA emulation. It includes the minimum and maximum template sizes which has been supported by the FPGA. The computation time of the circuit is been reduced by 50% compared to the circuit proposed in one of[3].

TABLE III

PERFORMANCE OF NCC CIRCUIT

Speed	100MHz	
FPGA	Xilinx Spartan III FPGA	
Template image size	Investigated window size	FPGA emulation time(ms)
Same size investigated window		
256×256	640×480	4.02
64×64		8.63

The simulation results for Template image 64×64. Consider 2 template images, after performing template matching operation, will get the output image.

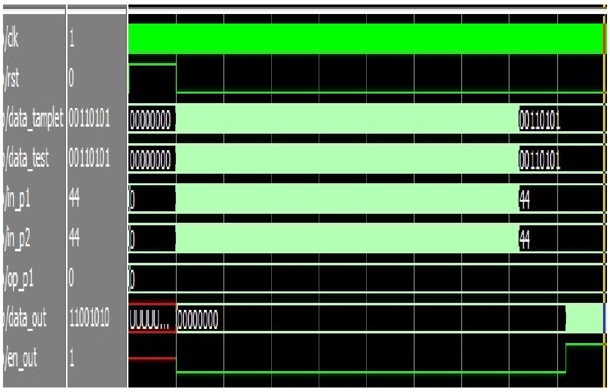

Fig 6 Simulation results for template matching.

IV. CONCLUSION

A FPGA implemented template matching module which speeds up the time consuming normalized cross-correlation (NCC) template matching has been presented. We have been modified the original NCC algorithm to accelerate the computation speed of the Circuit. Based on the algorithm we have developed a pipelined architecture with parallel processing unit which enchance the performance. Experimental results showed that our FPGA module results in less power consumption and hence the chip area is also been reduced. Furthermore, this module can also be applied to Automated vision applications such as object recognition, printed circuit boards , wafers etc.,

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