A Special Hardware for Detection of Attaching or Overlapping Objects

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Abstract

A high-speed processor for the recognition and location of object features is presented. The system is equipped with a powerful coprocessor to compute the normalized cross-correlation. An application in industry demonstrates the systems benefits.

Flexible systems for industrial automation demand sophisticated techniques for visual observation of the scene. Completeness checks, alignment and gauging as well as forms of dimensional checks require the ability to precisely locate object features in an image. In industrial environments one has to cope with the presence of noise in the images, image degradation, variations of lighting as well as variations of the visual appearance of the objects of attention.

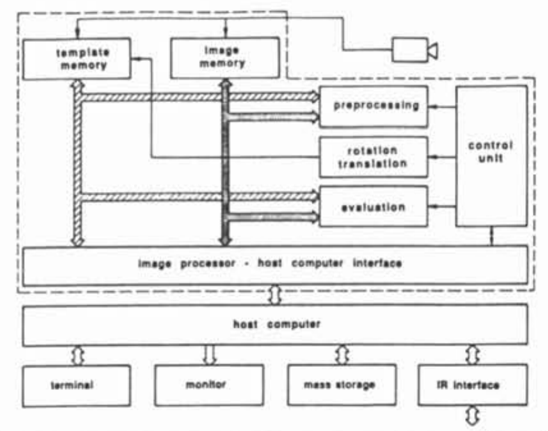
Finding the position of a feature of interest in an image can optimally be done by template matching, measuring the similarity between a reference pattern (template) and portions of the image. The research community has been using the normalized correlation to compute similarity measures for feature matching for years /Pratt/. For practical applications the benefits of normalized correlation were obstructed by its enormous computational cost, making it improper for real-time applications on availabe processing hardware.

Instead approaches were made based on edge detection methods trying to extract higher level information to perform faster search in a feature space with substantially reduced amounts of data /Hättich/. These approaches were restricted to few practical applications due to the efforts needed to maintain a sufficient performance under industrial conditions, the methods and algorithms used still being far from perfect.

We consider template matching by normalized correlation search a very effective method to locate features in an image if the performance of the method is improved by proper use of todays technology. A system to perform template matching in real time was reported /Silver/. Unfortunately for many industrial applications, this system does not perform rotation of the templates while computing the correlation coefficients.

The IPK-TEMAP

Triggered by inquiries from industry, the researchers at IPK started developing their own system hardware to perform normalized correlation search. The extraordinary speed of the system is primarily achieved through the special coprocessor. It computes the necessary transformations according to the chosen translation and rotation, as well as the necessary multiplications and additions for the autocorrelation and cross-correlation, using the well known algorithm for normalized cross-correlation /Pratt/. Figure 1 shows the structure of the TEMAP. Only those computations that are not time-critical are left to the host computer.



VISION SYSTEM STRUCTURE figure 1 IPK BERLIN

The host computer controlling the system is a basic MC 68000. Chosing a 68030 CPU would not result in major gain in speed since the burden of computation lies on the coprocessor. The systems VME-bus offers the option to integrate other hardware components.

The coprocessor is designed to perform 70 MOPS (mega-operations-per-second). This is achieved by a 4-level pipeline-architecture.

The systems specifications are as follows:

Hardware:	- MC 68000 CPU, 10 MHz - Hardware correlator, pipeline architecture, 70 MOPS - I/O board - Standard VME - bus
Greylevels:	256
Resolution:	256 x 256
Cameras:	4, CCIR
Software:	Image Basic, CP/M
Interfaces:	4 RS232C 4 Input 24 V 4 Output 24 V

The users may specify the parameters of the search procedure in a training phase. First, the pixels considered to belong to the templates have to be chosen.

Then, depending on the underlying spatial frequencies, the spacing parameters of the search can be set. Finally, as a result of training the system, the users can determine the optimal acceptance threshold.

The search procedure is structured into two parts, starting with a rather indistinct evaluation of candidates and ending with precise determination of the translatory and rotatory parameters up to sub-pixel precision.

Applications

For automotive industries a system was developed to automatically find stacks of metal parts in a box. The position of the highest stack had to be computed as well as the height in order to give a robot control the necessary data to pick the topmost part with a specially designed gripper. The drawbacks of the task were

- the parts overlap in the images,
- the bottom of the box and the floor have an irregular structured appearance,
- the actual height of the stacks influences the size of the objects in the image,
- the parts may be tilted to a certain degree, angles do not remain constant,
- a constant lighting was impossible due to environment conditions.

The solution achieved used the unique TEMAP. The fast computation of the normalized correlation coefficient was accompanied by the implementation of intelligent search techniques. The maximum of the coefficient can be found for every possible position and orientation, resulting in a three-dimensional correlation space. The height of the stacks was computed by analysing a 3-D-profile of the scene, achieved through stereo-imaging using the correlator to find parallaxis for corresponding regions. The overall time needed to compute the position of the first part in 3-D space never exceeded 10 sec., including positioning of the robot.

Other applications include gaging and inspection.

Further developments

Substancial gaines in speed using the normalized cross-correlation can be achieved through application of more sophisticated intelligent techniques to guide the search, thus minimizing the number of potential peaks of the correlation-function.

Since the time needed to compute the coefficient depends on the number of pixels used for the template, further improvements can be expected by intelligently reducing this number. Experiments show good results with templates reduced by a factor of up to 90 %.

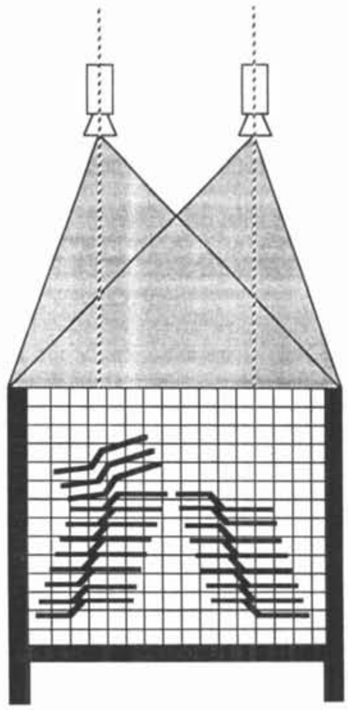


figure 2 setup of cameras to determine height and position of stacks

figure 3 TEMAP system

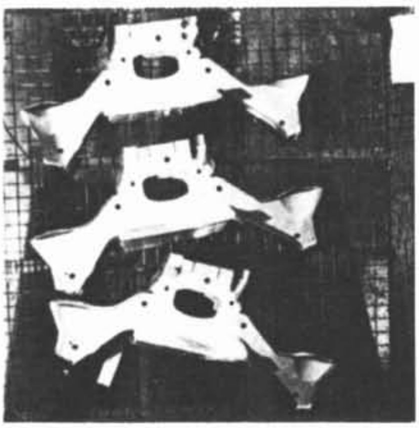


figure 4 stacks as seen from the camera position

References

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