DICTA-9I Digital Image Computing: Techniques and Applications
Royal Exhibition Building Conference Centre, Melbourne 4-6 December 1991
ed. A.J. Maeder and B.M. Jenkins *Australian Pattern Recognition Society* ISBN 0 646 07338 9

FAST OBJECT RECOGNITION AND LOCATION AT AN UNKNOWN SCALE

Alan L Harvey
Communication & Electrical Engineering Dept
RMIT Melbourne 3000 Australia

Harvey A Cohen
Computer Science & Computer Engineering Dept
La Trobe University Bundoora 3083

ABSTRACT

Image object location for machine vision applications using template matching is computationally very expensive when object size and location are unknown. Coarse fine strategies are described that speed up the identification of objects of unknown scale and position. In the coarse scale stage templates at widely spaced scales are used whereas in the coarse positional stage, large steps in position are made. In both cases, smaller steps are then made as dictated by an error criterion. A sparse template technique, previously used for known scale images is also applied to speed up searches by a factor of 40 or more for larger templates. A 4:1 range of scale factors was investigated.

INTRODUCTION

In robot assembly operations, the identification of objects and their positions within an image taken with a vision system is required to allow the robot to locate the objects. In general, parts may vary in position, orientation and scale. This paper describes speed up methods for searches for objects of unknown scale and position. Further work is likely to show that these methods will apply to objects of arbitrary orientation. Objects within an image may be identified by translating templates of the objects over the image until a match is found. If an exhaustive search is made at all image positions with many templates of significant size, very large amounts of computer time may be expended before completing the search. This paper describes methods for speeding up template searches for an image object. The speed up methods described are a coarse fine search technique and a reduced template technique. These techniques have been used together to achieve speed up factors of over 60:1.

KNOWN SCALE OBJECTS

In the coarse-fine search technique a coarse search is made until an indication of an impending match is found. At this point a fine search a: every column position is made. The criterion used is the rate of change of the template-image matching error as the template approaches the correct match. Figure 3 shows the rate of change of this error for the pebbles image as the template passes through the correct location for the image patch.

UNKNOWN SCALE OBJECTS

Coarse-fine techniques may also be used for objects of unknown scale. A plot of matching versus scale for the image investigated shows that the matching error dip has a considerable width indicating that steps of 10% may be used for the template set for this image. These results were first presented at IREECON-91 in Sydney.

TEMPLATE PREPARATION

A template of size 96x44 was cut from the pebbles image at row zero, column 30. This template was then scaled using pixel interpolation within a range 50 to 200 percent of the original image size. Linear interpolation was used, ie if the pixel position was half way between columns, the grey scale of the pixel was calculated on the basis of 0.5 times each pixel grey scale value. Scaling was done using fractions calculated using the modulo function, rather than using floating point. This speeded up scaling calculations by a factor of 10 for a 386 based machine without coprocessor.

COARSE FINE COLUMN SEARCH

As a first approach to object location in an image, the byte map to be matched to the image may be moved over the image, column by column, row by row and matching calculations made. Clearly if the matching calculations could be made at a reduced number of locations, ie a coarse search at say every fourth or fifth pixel then a large speed up in the matching operation could be made. If a check is made by comparing the current matching error with the error calculation at the previous position then a decision may be made to move along say four or more columns if the error is not moving towards a match. Alternatively, if the matching error is decreasing rapidly, then the bit map would then be moved along column by column. Investigations showed that the bit map may be moved along up to 6 columns for the coarse search and still always find the matching position. A five to one speed up was obtained in this way. Similarly, a coarse fine (reduced) column search using some change in the image matching criterion between rows will give a speed up factor of the order of four or five to one assuming the similar spatial changes in the vertical and horizontal direction. However matching error information is not as readily available as it was in the case of the reduced column search. The matching error change method used was to save the lowest value of the matching error for the previous two rows and make a coarse fine search decision on the basis of the difference..

SPARSE TEMPLATE MATCHING

Instead of using the entire bit map array to match against the image it is reasonable to use less than the total template array by employing a multigrid approach. Template and image brightness values on a 4x4 grid for example would reduce the number of image calculations by a factor of 16. A 16x16 row column grid was used giving a highly significant reduction in template matching calculation time. It should be noted that the images and templates in this study are noise free, ie there is no difference between template and image apart from scale. If there are differences, as there will be in most practical searches, a full template or at least a fuller template should be used when there is an indication of an eminent match. This could be achieved by using the change in the image matching function to switch to a full search rather than sub-sampling when there is an indication that the search is close to the vicinity of the object. See [8].

RESULTS

Coarse-Fine Search Technique Fixed Scale

Searches for the template taken from pebbles gave the results shown on the upper diagram, Table 2. The graph shows a plot of the Chebyshev matching function, the sum of the absolute differences versus the image column number for the correct row number, ie the row number where the template was actually found, row 0 column 30. In this diagram a matching calculation was made at every column position, ie a fine search .The column for the correct match was column 30. This point shows up very clearly on the graphs. The third figure shows the results for a coarse fine search where the template was moved either five columns or one column depending on the change in the error matching function. Again the correct column is clearly detected even when the partial search method is used. ie a calculation at all column positions.

Sparse Template Results Fixed Scale

As discussed, image search times may be reduced by speeding up the correlation calculation by a template image coarse-sampling method. For this test, a full search was made for all sets of results. Results are as expected, with search times dropping rapidly with greater and greater sub-sampling. The sub sampling table shows search times for reduced row and column sampling as specified. It should be noted that the case taken was essentially ideal as no image noise was introduced to the image. Sparse template results were for an exhaustive column and row search, ie matching calculations were performed at all row and column positions .

Sparse Template Results

row,column spacing	search time seconds
1	43.12
2	11.64
4	3.57
8	1.60
16	0.93

Coarse Fine Column Results

Column step pix	search time seconds
1	42.7
2	22.1
3	15.4
4	12.1
5	9.9

Varying Scale Results

The diagram of scale versus minimum matching error shows a significant correlation region around the point of correct scale. Depending on the number of objects to be found, the scale steps would need to be reduced accordingly. The Template searches were started at the top left of the image and stopped where the template matching error dropped below a threshold. For the coarse fine column search results, sparse template spacing was held at 8 for row and column spacing but at 4 for the coarse fine row search.

CONCLUSION

For an object of known scale whose position is unknown, two

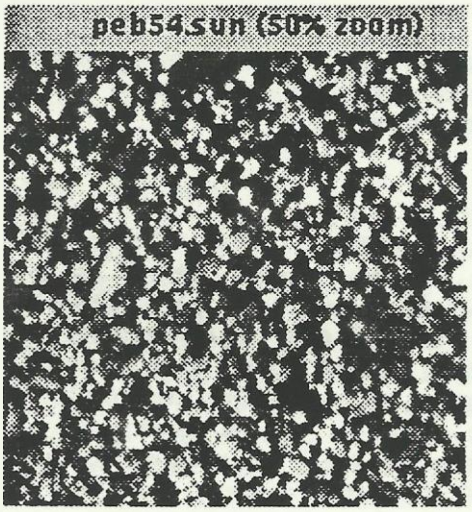
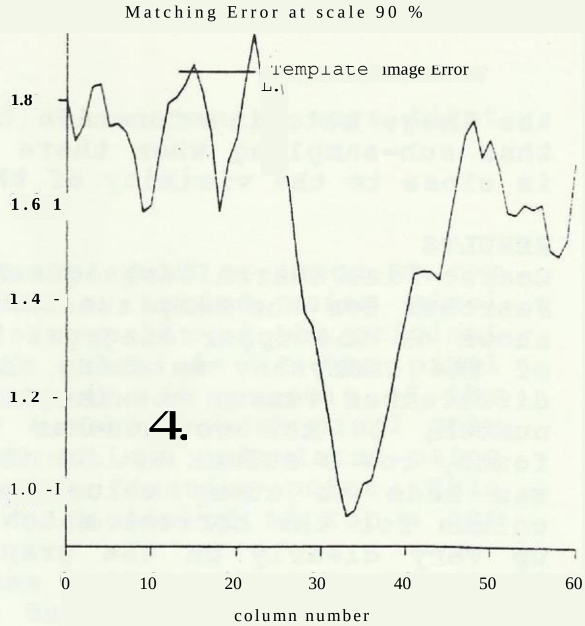


Fig 1. Pebbles Image.



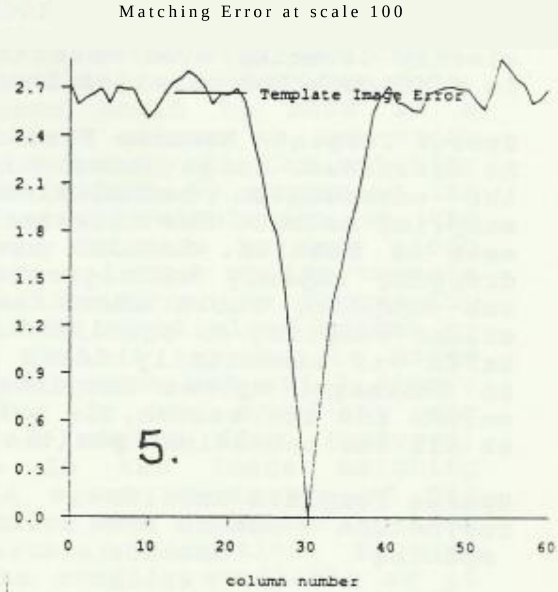
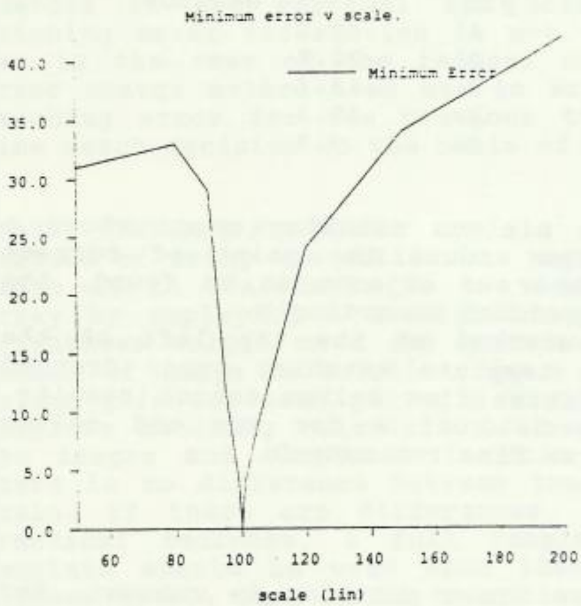
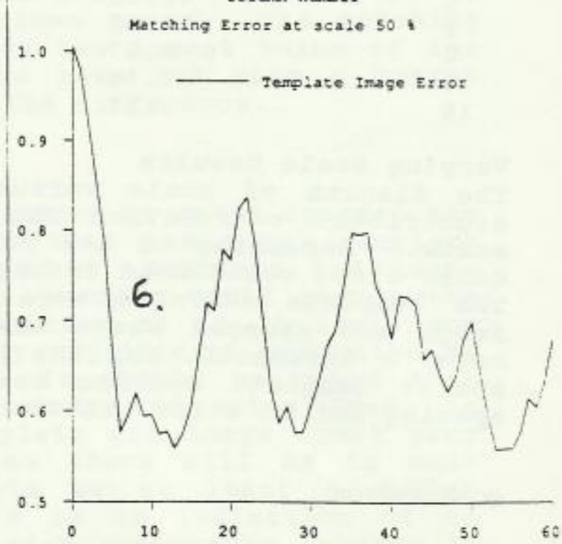


Fig. 2. Pebbles T

Fig. 3. Minimum error v scale





recognition speedup methods, known as a coarse fine search method and a sparse template technique have been described and used successfully for grey scale images to reduce search times. Regarding image templates of unknown scale, an investigation of matching error was made for templates scaled over a 4:1 range. For this textured image, the correlation effect extends well beyond 10% above and below the nominal image size. These results show that finite steps of 10 percent or more may be used for template scale steps for object searches where scale is unknown for images of similar texture. The sparse template technique and coarse fine search technique may also be used in conjunction with the finite scale step technique. Tabulated results given in this paper show that sparse template and coarse-fine column speedup methods give speedup factors of many times greater than unity. Rosenfeld and Vandenberg have used a block average template method [7] for a reduced search but their method requires the computation of image block averages which this method does not require. Some time is required to compute the scaled template arrays, however. These results are for noise-free images and templates. More practical cases, with appreciable noise will show reduced speedup factors

REFERENCES

[1] Caelli T.M. Liu Z.Q. "Multi-object Pattern Recognition and Detection in Noisy Backgrounds Using a Hierarchical Approach" Computer Vision Graphics And Image Processing 44 pp296-306 1988

[2] Caelli T.M. Liu Z.Q "On the Minimum Number of Templates required for Shift, Rotation And Size Invariant Pattern Recognition" "Pattern Recognition" Vol 21,No3 pp205-216 1988

[3] Gonzalez R. is Wintz P. "Digital Image Processing" Reading, MA Addison-Wesley 1977.

[4] Grimson W.E.L. "Recognition of object families using parameterised models Proc. Intnl Conf Computer Vision London UK, IEEE-CS1987 pp93-101.

[5] Harvey,A.L.Cohen H A "Fast Recognition of Objects of Unknown Scale." IREECON-91 Sydney 1991 pp138-141.

[6] Harvey, A.L. Cohen H A "Speed Up Methods for Image Object Recognition" ICARCV-90 Singapore 1990 pp 955-968

[7] Rosenfeld A. Vanderberg G.J "Coarse fine Template Matching IEEE Trans. Syst, Man, Cybern.pp104-107 1977