METHODS FOR FAST IMAGE OBJECT RECOGNITION IN ROBOTICS

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ABSTRACT
In Vision guided robotic operations, the rapid location and identification of image objects for assembly is essential. The image object data taken with a ccd camera may be in the form of a grey level, binary or colour image. This paper discusses our work on new speed up methods for object recognition in binary and grey level images. These are a coarse/fine stepping method and a sparse template technique. An extension of the coarse fine technique to give larger speedups is discussed.

INTRODUCTION
Searches for objects within images are extremely computationally expensive when scale, position and orientation of objects within the image is unknown. This paper reports results of a comprehensive coarse-fine object location program in which the criteria for coarse to fine switching have been investigated. These methods can speed up the column and row position search by a factor of 64. A matching error function is used to switch between coarse and fine search modes. Also a sparse template technique is used to give a further 64 fold speed up even more a for larger templates. This paper reports position search speed up times obtained on a number plate reading project. This work is of importance in vision guided assembly operations where machine vision techniques are used for locating parts and was first applied to a vehicle number plate location system.

COARSE FINE COLUMN SEARCH
By applying a reduced column search technique to object location in an image, a large reduction in computation may be made. A basic approach is to move the template over the raster scan image, computing the mismatch function at each pixel location. 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 pixel position, then a decision can 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, from A to C in Fig 5, then the template pixel array will be moved along column by column after each calculation. Investigations showed that the template map may be moved along six columns for the coarse search and still find the matching position. A five to one speed up was obtained in this way. It is important to note that speedup factors are image dependent.

COARSE FINE ROW SEARCH
Similarly, a coarse fine (reduced) row search using a change in the image matching criterion between rows as a switch will give a speed up factor of the order of four or five to one assuming similar spatial changes in the vertical and horizontal directions of the image. This will be the case for images of uniform texture. More structured images of an industrial nature will not be so predictable. However matching error information is not as readilv available in the case of the reduced row 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 this difference. An important point to consider in coarse fine searches is the dimensions of the template. A template four columns wide will have a much narrower correlation region than a 40 column wide template. Thus in certain cases for instance in the case of whole of image movement, where the template size is not fixed, it may be better to make the template longer (more columns) but not as wide, ie less rows if a coarse column search only is to be made.

SPARSE TEMPLATES
Matching error calculations may be speeded up by the use of sparse partial templates in which only say every fourth column and row brightness value of the template is checked against the image to be searched. A 16 times reduction in error calculations can be made in this way. For the case of noise-free images and templates, there is no need to use the full template. For the more practical case of differences between the image object and it's template, the full template would be used when the matching error indicates that a match is close to the current search position. As the template becomes more sparse, the chance of falsely switching to a full template becomes quite large, setting an upper limit to the sparseness of the template. Another way the template calculation may be speeded up is by the use of a smaller template array. For textured or fractal type images, this is an important option.

COARSE FINE SEARCH WITH BACKTRACKING.
By allowing the column search to reverse in direction, the coarse-fine search step may be doubled, doubling the coarse fine speedup. Since the translation can reverse, we can move to the far side of the correlation region, point B in diagram 5 during the coarse search and then move backwards to the point of best match, ie point D. This gives a further factor of four speedup to the coarse-fine row, column search,

APPLICATION TO OBJECTS OF VARYING SCALE
If a plot is made of matching error versus image size or scale a finite correlation region typically of the order of 10 pixels will be found for all but completely random images. On the diagrams page, diagrams two and three 2 and 3 on the last page of the paper for the pebbles image. This result indicates that a finite set of templates may be used to find the object of unknown scale by making coarse steps in the template scale to form a finite template library.
Again it is not necessary to perform a matching calculation over the entire template and sparse template techniques can also be used to reduce the number of matching calculations for each template. Sparse template techniques may also be used to reduce the calculation burden for each template. The number of competing template candidates in the image will also influence the template scale step required to differentiate between the template objects. Also see reference 5.

OBJECTS OF VARYING ROTATION

Of all the image processing geometric operations, image rotation is one of the most computationally expensive. The plot of matching error versus image rotation at a fixed location will again produce a finite correlation notch of the order of 10 pixels or so. This correlation region will be finite for all but random images. See the diagram below for the pebbles image. This result indicates that a finite set of templates may be used to find the object of unknown rotation by making coarse steps in the template angle to form a finite template library. Again it is not necessary to perform a matching calculation over the entire template and sparse template techniques can also be used to reduce the number of matching calculations for each template. Sparse template techniques may also be used to reduce the calculation burden for each template. Again the number of competing template candidates in the image will influence the template rotation step required to differentiate between the template objects. A paper covering this aspect will be presented at ICIP-92 in Singapore. See reference [5].

BINARY IMAGES

If the brightness of corresponding points of the image and the model or template differ, due to changes in illumination for example, then the matching error will not drop to zero even when the template is correctly positioned. To reduce this problem, images may be thresholded to black and white, ie a binary image. The grey level threshold may be chosen globally or by calculation of a local measure. As a large amount of information is thrown away by thresholding, it can be expected that the scope of the speed up techniques will not be as great with binary images. However, significant speed up factors are still attainable. The use of weighted templates has been investigated for binary images. The results show that greater discrimination and hence greater speedups are attainable using suitable weighting factors.

RESULTS

Sparse Template results for a template object of correct scale are given in the left hand table. As discussed, image search times may be reduced by speeding up the mismatch calculation by a template image sub-sampling method. For this test, a full search was made at all image column/row locations. Results are entirely predictable, with search times dropping rapidly with greater and greater sample spacing. Coarse/Fine Row Search results below illustrate the speed up factors obtained by varying the coarse row step for a template of correct scale but unknown position. Coarse fine positional searches for the template taken from pebbles, shown on diagram four, gave the results shown in the right hand table. The graphs 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.

Sparse Template Results		Coarse Fine Column Results	
row, column spacing	search time seconds	Column step	search time
1	43.12	1	42.7
2	11.64	2	22.1
4	3.57	3	15.4
8	1.60	4	12.1
16	0.93	5	9.9

Sparse template results were for an exhaustive column and row search. Coarse/Fine results were for a five row search and all template points.

Varying Scale Results

The graph in diagram 6 for error versus varying scale shows the effect on the mismatch dip of scale errors. Scales given are size information, so that 50% scale is actually 25% of the area. This diagram shows that a finite set of templates may be used for objects of varying scale and the object found reliably. If there are a large number of possible object candidates, the template scale step must be reduced in order to give greater discrimination. Sparse template techniques may be used in the preparation of the images to speed template preparation.

CONCLUSION

Two recognition speedup methods, known as a coarse fine search method and a sparse template technique have been proposed and tested for grey scale and binary images . Tabulated results given in this paper show that these methods give up to a 64 times coarse/fine search speed up factor and a similar speed up for the sparse template method for grey scale image translation searches. For binary images, translation searches can give at least a 16 times sparse template and a 4 to 1 coarse-fine column speed up respectively. The coarse-fine row search was not reliable for coarser templates. Rosenfeld and Vandenberg have used a block average template method [10] but their method requires the computation of image block averages which this method does not. This study has shown the significance of the width of the dip in the mismatch function in coarse-fine template matching. In particular, for a direct switch from coarse to fine search the coarse step size must be less than half the mismatch notch width. Using the extended coarse-fine strategy which uses back-tracking, the coarse step may be doubled to slightly less than the full notch width. While this paper covers translation and scale object searches, these methods will speed up of orientation searches as well. This work was first used in a vehicle number plate location investigation but has also been used for natural scenes involving textured images. These methods will still work in the presence of noise with some reduction in speed ups depending on the signal to noise ratio.

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Figure 1 Car Image

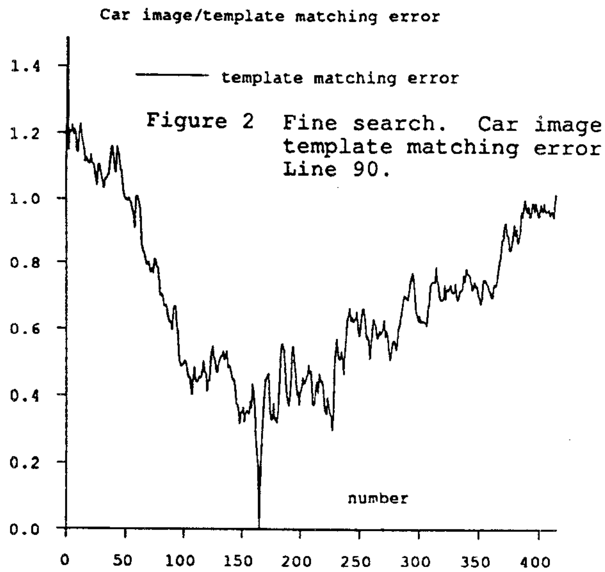

Figure 2 Fine search. Car image template matching error Line 90.

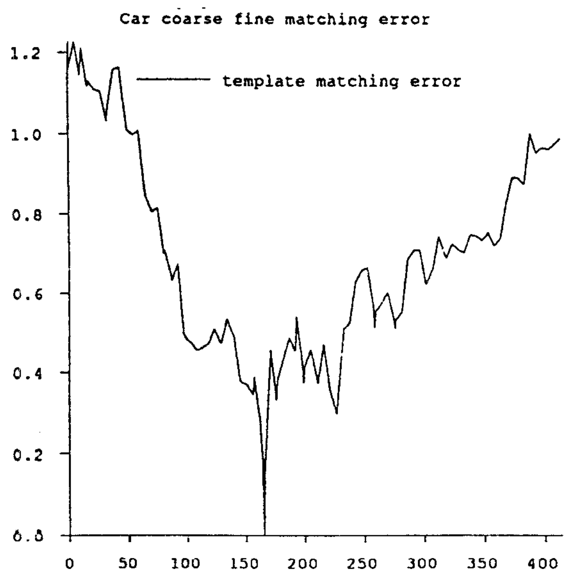

Figure 3 Coarse fine search Car image. Line 90.

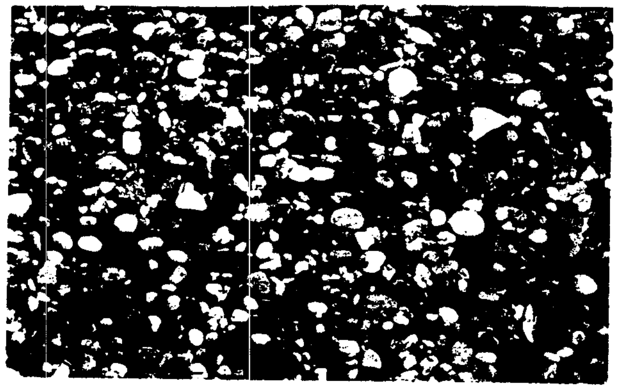

Fig 4. Beach pebbles.

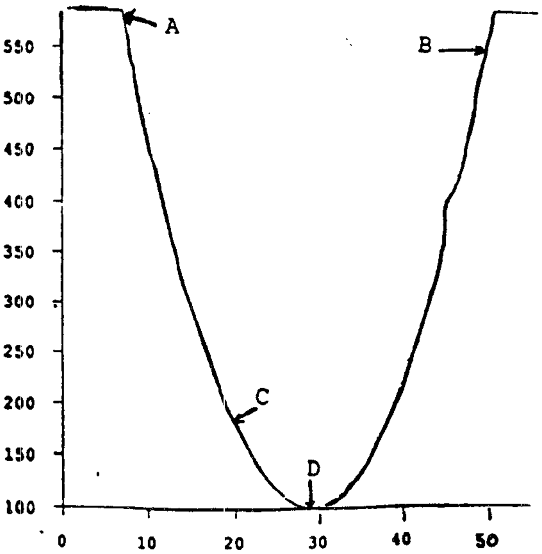

Figure 5: Proposed sequence of search for the coarse fine search technique.

Fig. 6 . Minimum error v scale