IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
ISSN (Online): 1694-0814
www.IJCSI.org

A Survey on Performance Evaluation of Object Detection Techniques in Digital Image Processing

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Abstract

In digital image processing , the performance evaluation means the analysis of parameters that improves the execution of the proposed system there by producing the optimized result. The image is defined as a Scene consists of objects of interest. To understand the contents of the image , one should know the objects that are located in the image. The shape of the object is a binary image representing the extent of the object. In Digital Image processing the shapes are represented and described in various methods .Shape representation method results in a non numeric representation of the original shape (e.g.) a graph. So that the important characteristics of the shape are preserved. The shape description refers to the methods that result in a numeric descriptor of the shape and is a step subsequent to shape representation .Skeletons are one such shape descriptors. The skeleton of a two-dimensional object is a transformation of the shape object into a one dimensional line introducing skeleton shape descriptors. Many operations like shape representation and deformation can be performed more efficiently on the skeleton than on the full object, as skeleton is simpler than the original object. The parameters such as thresholds, bounds and weights have to be tuned for the successful performance of the object recognition system. This paper provides an overview of estimating the parameters for performance evaluation of the object detection techniques, and a survey of Performance evaluation of junction detection schemes in digital image processing.

Keywords: *Performance analysis, Roc analysis, Performance Criteria, Parameter selection, Junction detection.*

1. Introduction

In any system that are newly developed , it is highly recommended to go for testing or sample execution. The output of the system with the user input data is compared or analyzed against the expected output with the system defined data. After such analysis ,It is identified that some of the factors used in the system may affect or change the expected output .Such factors need to be changed for the improved output or the result .Those factors are called as parameters. Parameters are those combinations of the properties which suffice to determine the response of the system. Properties can have all sorts of dimensions, depending upon the system being considered; parameters are dimensionless, or have the dimension of time or its reciprocal [1]. This paper provides a summery of object detection techniques , the parameters involved ,performance criteria investigated and evaluation of different junction detection schemes.

2. Background

The performance analysis, more commonly today known as testing , is the investigation of a program's behavior using information gathered as the program executes (i.e. it is a form of dynamic program analysis, as opposed to static code analysis). The usual goal of performance analysis is to determine which sections of a program to optimize - usually either to increase its speed or decrease its memory requirement (or sometimes both).

2.1 Algorithmic efficiency.

In computer science, efficiency is used to describe properties of an algorithm relating to how much of

IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
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www.IJCSI.org

various types of resources it consumes. The two most frequently encountered are

1. Speed or running time - the time it takes for an algorithm to complete, and
2. Space - the memory or 'non-volatile storage' used by the algorithm during its operation, but also might apply to
3. Transmission size or external memory such as required bandwidth or disk space.

The process of making code as efficient as possible is known as Optimization and in the case of automatic optimization (i.e. compiler optimization) - performed by compilers (on request or by default) - usually focus on space at the cost of speed, or vice versa. To analyze an algorithm is to determine the amount of resources (such as time and storage) necessary to execute it. Most algorithms are designed to work with inputs of arbitrary length. Usually the efficiency or complexity of an algorithm is stated as a function relating the input length to the number of steps (time complexity) or storage locations (space complexity).Algorithm analysis is an important part of a broader computational complexity theory, which provides theoretical estimates for the resources needed by any algorithm which solves a given computational problem. These estimates provide an insight into reasonable directions of search of efficient algorithms. Exact measures of efficiency are useful to the people who actually implement and use algorithms, because they are more precise and thus enable them to know how much time they can expect to spend in execution.

2.2Optimization techniques

The fig 1 figurative representation depicts the various techniques available.

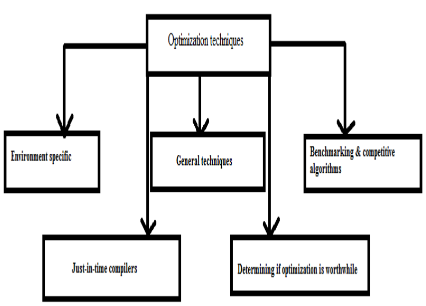


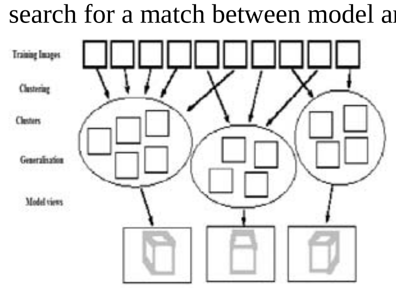
Fig.1

3. Methodology

For performing the performance analysis, first a model should be developed. Secondly, the proposed system with the selected parameters is designed. Finally a matching or testing is performed with that of the model and the proposed system is done. If the Proposed system produces the expected output/result then the selected parameters are the optimizing parameters and are said to support the performance of the proposed system. Otherwise the selected parameters are to be modified and new set of parameters have to be estimated for the better performance of the proposed system. Performances of various cornerness measures are discussed with respect to four performances of robustness: detection, localization, stability and complexity.[2]object recognition systems almost inevitably involve parameters such as thresholds, bounds and weights[3]. The selection of parameters is a critical one for the system to perform successfully. The manual method performs parameter estimation in an ad hoc way by trial and error. A combination of parameters is selected to optimize the objective function and the optimum is compared with the desirable result in the designer's perception and the selection is adjusted. This process is repeated until a satisfactory choice , which makes the optimum consistent with the desirable result, is found.[4]

3.1Learning model

We describe how to model the appearance of an object using multiple views, learn such a model from training images, and recognize objects with it in fig 2. The model uses probability distributions to characterize the significance, position, and intrinsic measurements of various discrete features of appearance; it also describes topological relations among features. The features and their distributions are learned from training images depicting the modeled object .A matching procedure, combining qualities of both alignment and graph sub isomorphism methods uses feature uncertainty information recorded by the model to guide the search for a match between model and image [5] **.**



IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
ISSN (Online): 1694-0814
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Fig.2Learning a multiple view models from training images requires a clustering of the training images and a generalization of each cluster's content. .

3.1.1Learning appearance models

Learning a multiple-view model from real images requires some means of comparing and clustering appearances. Although several researchers have clustered images rendered from CAD models and thus avoided the feature correspondence problem, only a few have clustered real images. Among them,[6] measures the similarity of an image pair as the proportion of matching shape features, whereas[7] use a vector clustering algorithm with fixed-length vectors encoding global appearance.

3.1.2Parameter estimation for optimal object recognition

They use coordinate system from geometric features ,did match quality measure, estimate feature mach probability, estimating aligning transformation, and derive matching procedure for learning model.

3.2Designing the proposed system

A common method is to generate a variety of input images by varying the image parameters and evaluate the performance of the algorithm as algorithm parameters vary. Operating curves that relate the probability of mis parameter setting. Such an analysis does not integrate the performance of the numerous operating curves. This process involves 1.Identifing the object .2.Select the key features of that object 3. Identify the junctions(keys)

3.2.1.Identifying the Object

The basic idea is to represent the visual appearance of an object as a loosely structured combination of a number of local context regions keyed by distinctive key features, or fragments.[8] A local context region can be thought of as an image patch surrounding the key feature and containing a representation of other features that intersect the patch. Now under different conditions (e.g. lighting, background, changes in orientation etc.) the feature extraction process will find some of these distinctive keys, but in general not all of them. Also, even with local contextual verification, such keys may well be consistent with a number of global hypotheses.

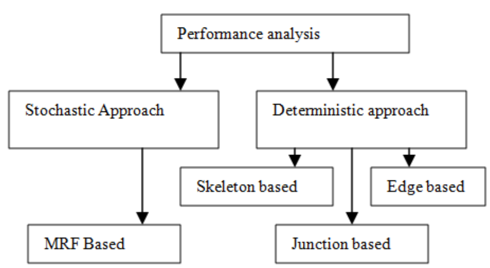
3.2.2.Parameter Selection

A fundamental component of the approach is the use of distinctive local features we call *keys*. A key[9] is any robustly extractable part or feature that has sufficient information content to specify a configuration of an associated object plus enough additional, pose-insensitive (sometimes called semi-invariant) parameters to provide efficient indexing. The local context amplifies the power of the feature by providing a means of verification.

3.2.3. Identifying the Junction

The recognition technique is based on the assumption that robustly extractable, semi-invariant key features, which are subsequently verified in local context, can be efficiently recovered from image data[10]. More specifically, the keys must posses the following characteristics. First, they must be complex enough not only to specify the configuration the object, but to have parameters left over that can be used for indexing. Second, the keys must have a substantial probability of detection if the object containing them occupies the region of interest (robustness). Third, the index parameters must change relatively slowly as the object configuration changes (semi-invariance). From a computational standpoint, true invariance is desirable, and a lot of research has gone into looking for invariant features [11].

4. Performance Analysis frame work



earance of an object as a l

Fig.3

From the literature in a digital image, one can basically distinguish between two approaches as in fig 3.and each of them corresponds in some way to the processing of one component in the decomposition above.

1. The stochastic approach, which is based on the modeling of an image as a realization of a random

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process. Usually, it is assumed that the image intensity derives from a Markov Random Field and, therefore, satisfies properties of locality and stationary, i.e. each pixel is only related to a small set of neighboring pixels and different regions of the image are perceived similar. This modeling is particularly adapted for texture images (thus to the processing or the component u2 in the previous decomposition) and has motivated numerous works on texture analysis and synthesis [12].
2. The deterministic approach, whose main purpose is to recover the geometry of the image.

4.1Markov Random Field Approach

A pioneering work on the recovery of plane image geometry is due to[13]. They did not directly address the problem of recovering missing parts in an image but rather tried to identify occluding and occluded objects in order to compute the image depth map. Their algorithm starts with the detection of the boundaries of image objects. The next step is the identification of occluded and occluding objects. To this aim, [13] had the luminous idea to mimic a natural ability of human vision to complete partially occluded objects, the so-called a modal completion process described and studied by the Gestalt school of psychology and particularly[14] .

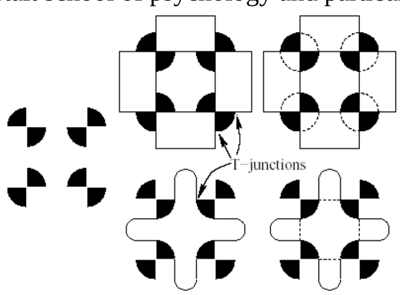

Fig 4.T-junction

The theory is applied to a specific model of MRF recognition presented in[15].The process is based on supervised learning process. Correctness, instability and optimality are proposed as the three level criteria for evaluating the parameter estimates.

4.2. Skeleton based approach.

Superiority of skeleton is that it contains useful information of the shape, especially topological and structural information. To have skeleton of a shape, first boundary or edge of the shape is extracted using edge detection algorithms [16] and then its skeleton is generated by skeleton extraction methods [17] Medial axis is a type of skeleton that is defined as the locus of centers of maximal disks that fit within the shape [18]. We use medial axis as the skeleton of shape. In [19] they present an algorithm for automatically estimating a subject's skeletal structure from optical motion capture data without using any *a priori* skeletal model. In [20].Other researchers have worked on skeleton fitting techniques for use with optical motion capture data. In [21] describe a partially automatic method for inferring skeletons from motion. They solve for joint positions by finding the center of rotation in the inboard frame for markers on the outboard segment of each joint.
The method of [22], like ours, works with distance constraints although they still rely on rotation estimates. They assume that the skeletal topology is known beforehand and use heuristics to test multiple possible marker assignments. Similar problems have also been studied in the biomechanics and robotics literatures. A few specific examples of methods for inferring information about a human subject's skeletal anatomy from the motions of bone or skin mounted markers can be found in [23]. In [24]they have published a survey of calibration by parameter estimation for robotic devices .

4.2.1 Parameter used.

They determine the skeleton's topology and the locations of the connecting joints. Both are determined by minimizing the same quantity, called the joint cost. A joint between two segments in an articulated skeleton should maintain a constant distance from the markers in marker groups for both segments. To avoid excessive computational costs we only solve the all pairs joint optimization approximately, then once we know the skeleton topology we solve for just those joints more accurately. The parameter used is the junction cost and the performance criteria are Topological connectivity, Qualitatively accurate structure, and non-linear optimization. In[25]They consider extracted skeleton as a connectivity graph such that junctions are considered as graph nodes and skeletal curve segments is considered as graph edges1. Connectivity graph perfectly represents topology of the skeleton and structure of the shape. Fig. 5 shows a sample shape, its skeleton and its connectivity graph.

4.2.2 Topological Information

We represent skeleton of a shape as a graph such that junction points are graph nodes and skeletal curve segments are graph edges. We call this graph

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ISSN (Online): 1694-0814
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as connectivity graph of the skeleton. Therefore, we may have for any given shape, its skeleton and its connectivity graph.

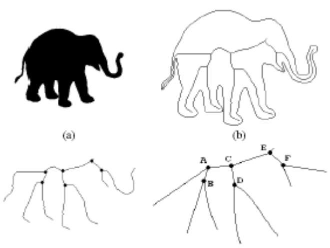

Fig.5.Shape and connectivity graph

4.2.3.Geometric Information

In order to include geometric information into our shape representation method, we need to a feature which captures convexities, concavities, thickness and thinness of different parts of a shape. This is achievable using "radius function". This function is defined and can be computed for all skeletal points. Radius function *R(p)* for point *p* on the skeleton is the radius of the maximal inscribed disc touches the boundary of the shape [26]. In fact, variations of this function along the skeletal points create convex or concave parts of a shape. This is shown in Fig. 6. As seen in this figure, fixed values of radii from A to B create a flat part and increases of radii values from B to C create a convex part in the shape.

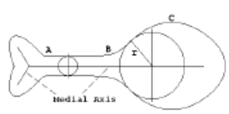

Fig.6.Geometric information

4.3Edge based approach.

In [27],They design and define the Performance by asking the following questions.
1.How exactly does one define Performance?.Issues that are need to be addressed are
2.What image population is relevant?
3.Is the performance evaluated independent of the algorithm?
4.How are difference in performance measured?
with previous work on quantitative performance evaluation is in edge detection and thresholding [28].Most of the papers present an analysis that is specific to edge detection.Furthermore,the performance is finally a number,(e.g.) percentage of edge points detected,etc. There is little further analysis of the sensitivity of performance to relevant factors such as the context of the edge.

4.4.Junction based approach

A strength of the methodology is that it can be applied to any detection problem. The line detection example developed in this paper was for demonstrating the application of this methodology.This methodology has been partially adapted for performance evaluation of object recognition algorithms[29] and machine inspection algorithms[30].The key steps to applying this methodology to any algorithm are(i)converting the algorithm into a detection algorithm,
(ii) choosing the appropriate signal variable to use as the threshold.
Another appropriate example where our methodology could be used is the detection of corners and junctions[31].

4.4.1. Evaluation of Junction Detection schemes

In general ,The frame work is described as follows in the fig 7.

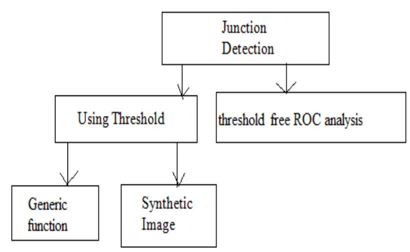

Fig 7 Junction detection schemes

A number of different methods have been proposed to evaluate the various approaches to corner detection. The different methods can be classified into methods based on visual inspection, localization accuracy, and theoretical analysis [32]. Localization accuracy is another evaluation method and can be measured based on the correct projection of 3D scene points to 2D image points[33].Since this method requires the precise knowledge of 3D points, the evaluation is restricted to simple scenes of, for example, polyhedral objects. The performance of various corner detectors can also be assessed by theoretical analysis[34]. Analytical studies are limited to particular configurations such as L-corners. Here we have introduced the method of ROC analysis in the context of junction detection. ROC analysis allows assessment of the capabilities of the

IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
ISSN (Online): 1694-0814
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detectors over the full range of possible thresholds for every test image. Consequently, ROC-based evaluation results are not flawed by choice of a particular threshold, which can strongly bias the obtained results.

4.4.1.1.Biologically motivated scheme for robust Junction detection.

In [35],the performance criteria is classified into two approches.
1.Based on threshold
2.Threshold free approach, where Receiver operator characteristic (ROC) analysis is used for a threshold-free evaluation of the different approaches.

4.4.1.1.1 ROC analysis.

Recently[36] studied the performance of human observers for the detection of junctions in natural images. Comparing [37] Unlike local approaches as proposed in computer vision [38], the new scheme is based on a more global, recurrent long-range interaction for the coherent computation of contour responses. In[39] various models namely, Models of Recurrent Long-Range Interaction[40] A comprehensive overview of these different approaches can be found in [41] Decoding Population Codes. [42]Circular Variance Function. [43] Multi scale Processing for Junction Detection [44] have been discussed.

4.4.1.2 Applying ROC for the Evaluation of Different Junction Detectors

ROC analysis allows characterizing different detectors over the full range of possible biases or thresholds. In virtually all junction detection schemes, some kind of thresholding is involved, and the detection performance crucially depends on the determination of the "optimal" threshold value. A threshold-free evaluation of different detectors as provided by ROC analysis allows separating the sensitivity of the detector from its threshold selection strategy. ROC analysis in general is based on ground-truth verification, that is, the comparison of a detection result with ground truth. Thus, the first step to apply ROC analysis for junction detection is the specification of ground truth junction points for each test image. For synthetic images, the ground truth position of junction points is known from the definition of the image or can be rather easily inferred from the gray-level variations. The ROC curve characterizing the detection performance of the particular method is obtained by plotting the true-positive rates against the false positive rates.To sum up, ROC analysis of the performance of junction detection schemes involves the following five steps:
1. Selection of an input image and determination of the ground truth position of junction points
2. Application of a particular junction detection scheme to the image
3. Normalization of the junction responses to the range [0; 1]
4. Variation of a threshold in *N* steps from 1 to 0 and computation of the respective true-positive *t*p and false-positive *f*p rate
5. Plot of the ROC curve, that is, plotting *t*p against *f*p The free parameters of the approach are the number of thresholds *N* and the error radius *r*err.

4.4.1.3Comparison of junction detection schemes

a)Evaluation of Junction Detection Based on Feedforward vs.Recurrent Long-Range Processing

In order to focus on the relative merits of the recurrent long-range interactions for the task of corner as in fig 4,and junction detection, the proposed scheme is evaluated using two different kinds of input, namely the activity W_θ of the long-range stage and the purely feed forward activity W_0 of the complex cell stage. Localization of Generic Junction Configurations**.** From the outset of corner and junction detection in computer vision, the variety of junction types has been partitioned into distinct classes like T-, L-, and W-junctions,[45], and more recently, *Ψ*-junctions [46]. In the first simulation we compare the localization accuracy of junction responses based on feed forward vs. recurrent long-range responses for L-, T-, Y-, W- and *Ψ*-junctions (Fig. 8). For all junction type , the localization is considerably better for the method based on the recurrent long-range interaction.

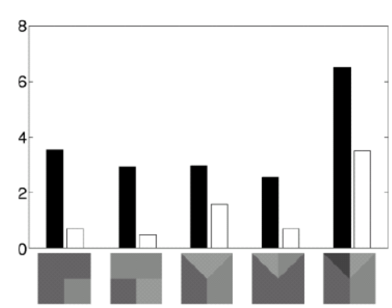

Fig.8.Processing of Images.

IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
ISSN (Online): 1694-0814
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They have also evaluated the junction detection performance on real world images, such as cubes within a laboratory environment (Fig. 9). At the complex cell stage, many false responses are detected due to noisy variations of the initial orientation measurement. These variations are reduced at the long-range stage by the recurrent interaction, such that only the positions of significant orientation variations remain. We have further employed ROC analysis for the threshold-free evaluation of the detection performance. The results show a better performance of the recurrent approach over the full range of thresholds (Fig. 3),

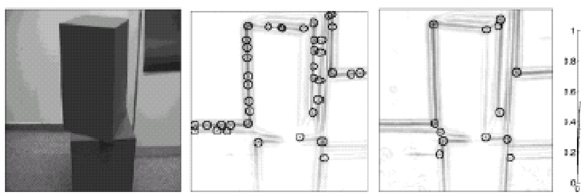

Fig.9. Processing of Images.

b)Evaluation of Detection Performance Compared to Other Junction Detection Schemes

In this section the author compared the new scheme based on recurrent long-range interaction with two junction detection schemes proposed in computer vision that utilize only localized neighborhoods, namely the structure tensor [47] Both schemes compute the .first- or second-order derivatives of the image intensity values, respectively. For a fair comparison of methods one has to ensure that all junction detectors operate on (at least approximately) the same scale [48]The derivatives used in the two standard methods are therefore approximated by Gaussian derivatives whose standard deviations are parameterized to .fit the successive convolution of filter masks used to compute the complex cell responses. We show the results of the ROC analysis when applied to a number of artificial and natural images, particularly a series of cube images within a laboratory environment (Fig. 4), and a second set of images containing an artificial corner test image from [49] a laboratory scene from[50] and an image of a staircase (Fig. 5). For all images, the ROC curve for the new scheme based on recurrent long-range interactions is well above the ROC curves for the other schemes, indicating a higher accuracy of the new method.

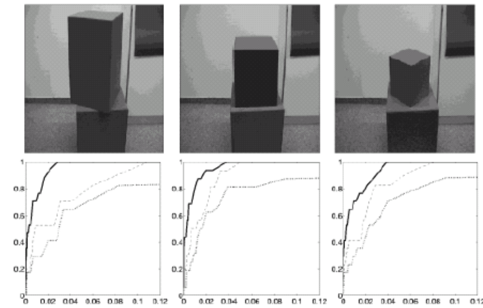

Fig.10.Top row.Images ; Bottom row.ROCanalysis

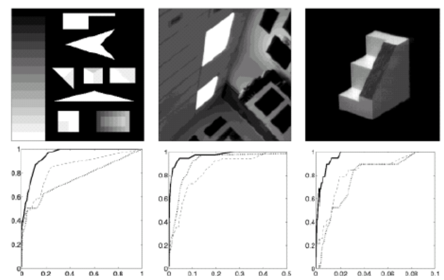

Fig. 11. Top row.Images ; Bottom row.ROCanalysis

5. Conclusions

In digital image processing, Junctions plays a major role in various perceptual tasks, such as the determination of occlusion relationships for figure-ground separation, transparency perception, and object recognition, among others. This paper provides a overall summery of various junction detection techniques and its performance evaluation. The new approach showing the superior performance of both synthetic and camera images called Receiver operating characteristics is also discussed. This paper will be useful for all visualization users who wish to proceed further in the field of object detection and reconstruction in digital image processing.

Acknowledgments

The author would like to express her gratitude to Mr. Dr .V.Sengoden, Principal and secretary,SNR SONS COLLEGE ,COIMBATORE for providing necessary infrastructure and for his constant encouragement that led to improvise the presentation of the quality of the paper.

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IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 6, November 2010
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ISSN (Online): 1694-0814
www.IJCSI.org
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