# Probabilistic Parser for Face Detection

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**Abstract**- In this paper, we have proposed probabilistic parser for identifying the face in a given scene image. Many object detection techniques use pattern statistical methods for feature extraction which is resource intensive and time consuming. We proposed a novel certainty factor based geometrical formulation for facial feature extraction. The proposed method accurately detects the facial components like eyes, nose and mouth in the presence of complex background. In the next stage, the AND/OR graph based recursive Top-down/Bottom-up image parser is used to detect the face in the input image by using the detected facial components. The image parser grammar represents both the decomposition of the scene image and the context for spatial relation by horizontal link between the vertices of the graph. The AND/OR graph is used to represent compositional structure of the image. The AND node represents the decomposition of the visual object into number of components and OR node represents the alternative sub-configuration /component. The experimental result confirms that our method outperforms some of the existing face detection methods.
***Keywords***- face detection; parse graph; bottom-up/top-down inference; Bayes formulation

## I Introduction

Face perception is an important part of human capability system. Given a single image, the objective of face detection is to identify all image regions that contain a face regardless of position, orientation and lighting conditions. A brief survey of face detection can be found in the paper [1]. Hitherto, Active research is to build a human like system but none is free from limitations. The progress in computer science of probability and image analysis is leading to revolution in image parsing. The parsing is a process of determining the parses of an input string according to a formal grammar. The weights are chosen to define a probability distribution over parses is called probabilistic parsing. Disambiguation is achieved by evaluating the parse tree with the highest probability. The supervised and unsupervised methods for parsing are proposed in the paper [2]. Parsing the contents of image has always been the main problem in object/face recognition task. The grammar and syntactic rules are extensively used and studied for language analysis but not for image analysis. We investigate the option of applying the image parsing for face detection task. The objective of the image parsing is to decompose the image into its constituent parts in a multilevel structure represented by a parsing graph. The main difficulties of the image parsing remain challenging even today for various reasons.

1. The vast contextual knowledge about the real world that has to be represented in the database.
2. The image parsing problems are NP-hard problem thus makes it hard in computational complexity.
3. The gap between the image and symbolic representation of the structured image models.

The criteria listed below motivates for using the probabilistic grammar for recognition task.

1. A general rules for visual knowledge representation and classification.
2. A recursive re ranking or Bottom-up/Top-down algorithms for parsing.
3. To learn new object instance from small set of parser rules.
4. To overcome the gap between pixels and symbols for each visual model at all levels. [3]

In the image analysis literature, face recognition and detection can be roughly divided into three cases.

(i) Appearance based approaches: It achieves visual representation based on appearance properties of individual object or object categories. An approach for face detection using cascade of classifier is proposed that can minimize computation time while improving detection accuracy

[4]. The main drawback of Appearance based method is that it cannot compensate pose, occlusion, or varied expressions.
(ii) Structure based approaches were introduced in the last 10 years to account for pictorial object representation and recognition. P F Felzenszwalb and Huttenlocher D P [5] presented a computationally efficient frame work for part based modeling and recognition of objects. Lutz Goldman Ullrich J M and Thomas Sikora [6] proposed component detection based on haar like feature with adaboost classifier and topology verification is based on graph matching technique.
(iii) Image parsing approaches were introduced in the last 5 years for object segmentation, detection and recognition.
In this paper, we have used the image parsing strategy to localize the face after the facial components are located through belief propagation methods. Fig 1 illustrates an image where it is divided in to three parts at the top level: two face regions and the background. These three components are further decomposed in to patterns. In principle, the decomposition can be continued until it reaches a specific visual criterion or identifiable components in the image. Fig 2 shows the face AND/OR parse graph. The nodes at the leaf level represent the component of the face pattern. The parsing graph is similar to parsing the statement of natural language. The rest of the paper is organized as follows. Section II describes the related work and Section III gives the details of the proposed system. Section IV explains the Experimental results. The conclusions are drawn in the Section V.

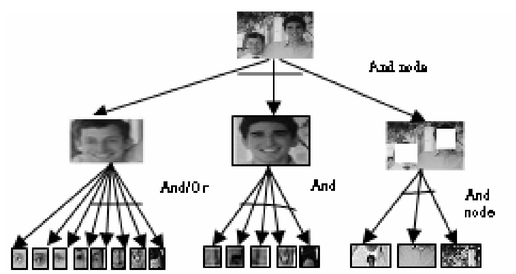


*Fig 1 shows the parse tree of the input image illustrating the task of image analysis. The parse tree includes structural decomposition and spatial relation.*

## II Related Work

The unsupervised learning of a probabilistic grammar for invariant hybrid object detection is performed using different aspects of the grammar where the object type, position and scale are not known in advance. Rin Dechter and Robert Mateescu [8] introduced a AND/OR search space analysis for probabilistic graphical models that includes the search based constraint processing and inference algorithm [7]. Feng Han and Song Chun zhu presented a Top down/Bottom up parsing method on man-made structures to recognize objects by using inference algorithm [9]. The proposed method can efficiently detect the facial features in the presence of poor illumination, in/out of plane rotation and varied expressions [10]. The eye localization in Binary Images by statistical method is proposed in the paper [11]. The novel visual category learning is proposed for man-made structures by using grammar induction rules [12]. The proposed method automatically generates a life like portraits using AND/OR graph representation but the drawback of the method is that it cannot generate the portrait of the image with wrinkles [13]. Zijian Xu, Hong chena and Song-chun zhu [14] presented a three layer generative model for face representation which is flexible to incorporate diverse representations of face components and skin features. The hierarchical compositional system is proposed for rapidly detecting the deformable objects like cats, horses in a scene mage by performing inference on compositional graph model [15]. Liang Lin, Tianfu Wu, Joke porway and Zijian Xu [16] proposed a generative model based on stochastic context free grammar (SCFG) for recognizing compositional objects with huge intra variance. It combines the power of SCFG to present variability of the object configuration and Markov random field to represent the spatial relationship between parts. In [17], Attribute AND/OR parse graph grammar is presented for event representation and recognition. The image segmentation and recognition is performed through the combination of top down and Bottom Up processing [18]. A F Bobick and Ivanov Y A [19] presented a method of combining the probabilistic model of simple gestures and higher level structural knowledge for task of activity and behavioral recognition. Long Zhu and Y Chen [20] proposed Probabilistic context free grammar and Markov Random Field (PGMM) that can perform rapid inference, parameter learning, and the task of structural induction.

Qiu Dan and Dudeck [21] reviewed the probabilistic certainty factor models and summarized that certainty factor proposition cannot be considered for belief updating. The belief propagation is an efficient tool for learning and inference which makes efficient parsing for NP hard problems [22]. The main contribution of this paper is in two counts. (1) The certainty factor based geometrical model for location of the facial components (2) The verification of the topology of the face using Image parsing method.

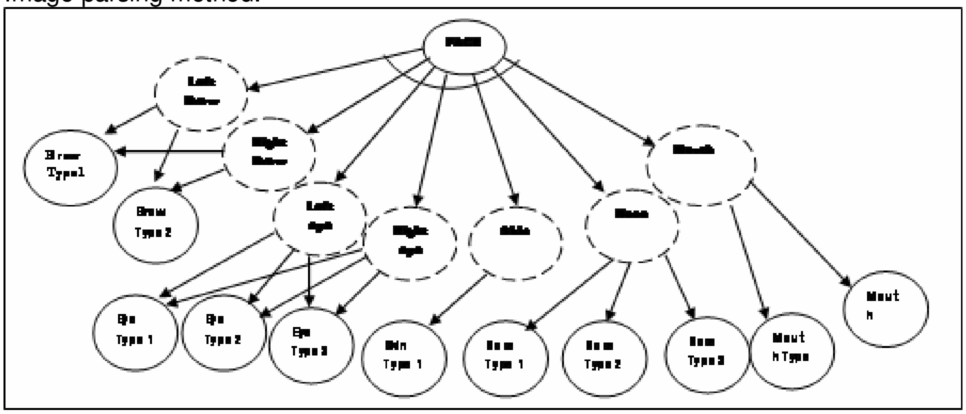

Fig 2 shows the AND/OR Face Graph

**III Proposed Method**

The proposed system is a two layer image parsing architecture and is shown in the Fig 4. The first layer extracts the facial feature components by using the Certainty factor based geometrical configuration. This layer accurately detects the main facial features of the input image. At the second layer, an AND/OR graph based recursive top-down/bottom-up function is used for image parsing to localize the face under the Bayesian formulation. Fig 3 shows the schematic representation of the recursive top-down/bottom-up strategy. The node A represents the input scene image, nodes A1, A2, A3 and A4 represents the non-terminal AND nodes. The AND node decomposes the object into components. At the leaf node layer, only the small visual categories are represented.

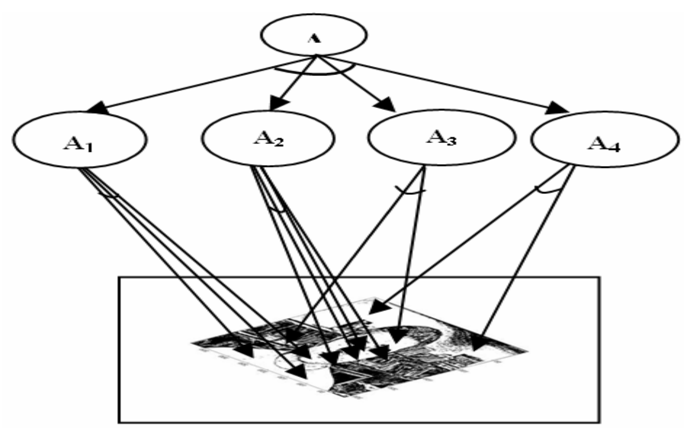


*Fig 3 Recursive Top-down/Bottom-up strategy*

The rest of this section is organized as follows. Section 3.1 describes the facial feature extraction and image parsing is provided in the section 3.2.

**3.1 Geometrical facial feature extraction with Belief propagation**

In this section, the facial components of the input image are extracted by using the certainty factor based geometrical model. Weildong Qu and Katsuhiko Shirai [23] described a robust algorithm for text categorization that makes use of inference mechanism with belief learning rules. In this paper we have used belief propagation to locate the eye regions in the probe image. Fig 5 (a) shows the typical geometrical configuration of the face image and 5 (b) shows the typical image after high boost and binary operation.

The unwanted information must be removed before location of the facial components. For this purpose high boost FFT filtering [24] is used to enhance the contrast between facial feature candidates and rest of the image. After high boost operation, the image is converted into binary image. In MYCIN expert system, Shortliffe and Buchanan defined a series of combination functions for certainty factors which can be used in uncertain situations [25]. The measure of Model Belief (MB) and Model Disbelief (MD) of the hypothesis h given observations e are computed from the following formulation

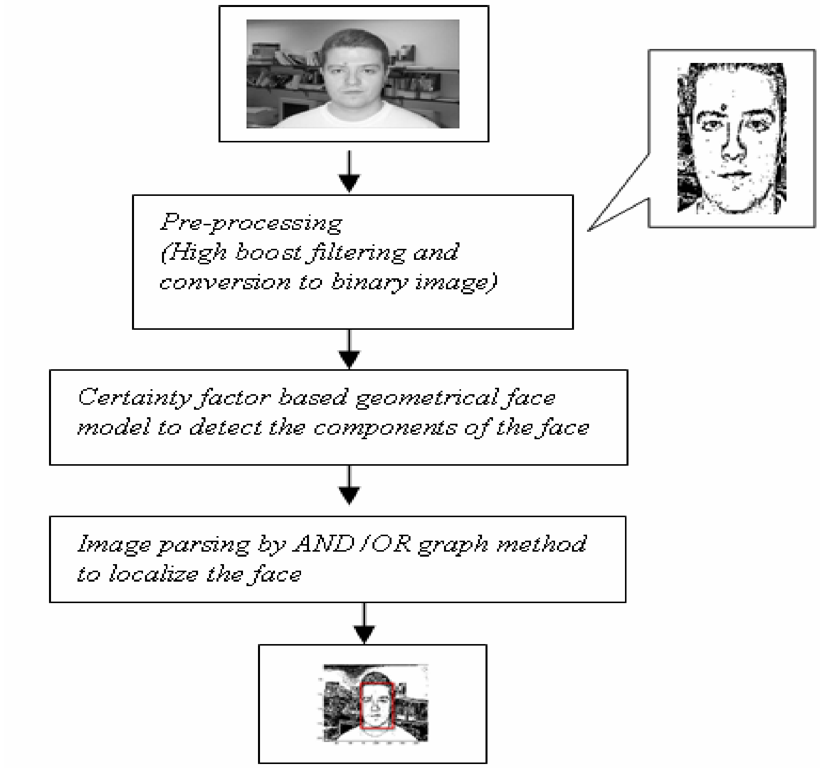


*Fig 4 shows the Architecture of the proposed system.*

5 (a) 5 (b)

*Fig 5 (a) shows the geometrical model of the face and (b) shows the high boost and binary image*

$$MB[E_{eye},e]=\begin{cases}1 & if P(E_{eye})=1\\ \dfrac{\max(p(E_{eye},e),p(E_{eye}))-P(E_{eye})}{(1-p(E_{eye}))p(E_{eye},e)} & otherwise\end{cases} \quad (1)$$

$$MD[E_{eye},e]=\begin{cases}1 & if P(E_{eye})=0\\ \dfrac{\min(p(E_{eye},e),p(E_{eye}))-P(E_{eye})}{(0-p(E_{eye}))p(E_{eye},e)} & otherwise\end{cases} \quad (2)$$

$$CF[E_{eye},e]=MB[E_{eye},e]-MD[E_{eye},e]\geq 0.8 \quad (3)$$

The Certainty factor CF measure modified by Heckerman [25] is used to detect the possible eye feature blocks in the input image. Many researchers have used random method to locate the possible eye blocks in the input image. Let $(x_1,y_1)$ and $(x_2,y_2)$ be the centers of right eye and left eye. The co-efficients of the base line ax+by+c=0 passing through eye candidates and angle θ between the base line and x-axis can be calculated as follows.

$a = y_2-y_1$, $b = x_2-x_1$ and $c= x_2y_1-x_1y_2$ and $$\theta=\tan^{-1}(-\frac{a}{b}),-\frac{\pi}{2}\leq\theta<\frac{\pi}{2} \quad (4)$$

The distance Dnose, Dmouth, Deyebrow represent the distance between the reference line and centers of the nose, mouth and eyebrow respectively (See Fig 5 (a))

The orientations $\theta_1$ and $\theta_2$, and distances $l_1$ and $l_2$ are calculated for the selected feature block. The $l_1$ is the length of the left eye and $l_2$ is the length of the right eye.

$$E_{lefteye}=\exp[-1.2*((l_1-\frac{l_2}{2})^2+(l_1+\frac{l_2}{2}-1)^2+(\theta_1-\theta)^2+(\theta_2-\theta)^2)]\geq 0.8 \quad (5)$$

$$E_{righteye}=\exp[-1.2*((l_2-\frac{l_1}{2})^2+(l_2+\frac{l_1}{2}-1)^2+(\theta_1-\theta)^2+(\theta_2-\theta)^2)]\geq 0.8 \quad (6)$$

If the evaluation of the equation (4) is larger than the threshold value 0.8, these two feature blocks are considered as eye features. The relative region in the geometrical model is searched for other facial candidates. Every feature block located within the region must be evaluated to decide whether it contains facial features or not. Let $(x_k,y_k)$ be the center of the nose block. The distance between from the center of the block to the base line can be calculated as

$$d_{nose}=\frac{|a\overline{x}_k+a\overline{y}_k+c|}{\sqrt{a^2+b^2}} \quad (7)$$

with constraint $(b\overline{x}_k-a\overline{y}_k+c_2)(b\overline{x}_k-a\overline{y}_k+c_5)<0$

The following evaluation function can be used to evaluate the feature block as nose feature.

$$E_{nose}=\left[-6*(\frac{dnose-Dnose}{D})^2\right] \quad (8)$$

This evaluation function ranges from 0 to 1.

In the similar manner the mouth feature is evaluated. Let $(x_i,y_i)$ be the center of the mouth feature block. The distance between the centers of the block to the base line can be calculated as,

$$dmouth = \frac{|a\overline{x}_k + b\overline{y}_k + c|}{\sqrt{a^2 + b^2}}$$

(9)

With condition $(b\overline{x}_k - a\overline{y}_k + c1)(b\overline{x}_k - a\overline{y}_k + c6) < 0$

The following evaluation function can be used to evaluate the mouth block feature.

$$E_{mouth} = \exp\left[ -2.4 * (\frac{d_{mouth} - D_{mouth}}{D})^2 \right] \quad (10)$$

This evaluation function also ranges from 0 to1. After the complete evaluation of the facial features, the topology of the face is verified by using the image parsing method.

### *3.2 Image parsing for localizing the face*

The proposed method uses AND-OR graph model to represent the scene. The OR nodes are individual components that choose between possible sub-nodes or children nodes. Only one child is assigned to each OR node during parsing. The AND node represents pictorial composition of children with valid topology. A max margin approach for parsing the sentence that makes use of Support Vector Machine (SVM) is provided in the paper [26]. The max-margin AND\OR graph method for parsing the human body to recover the pose is proposed in the paper [27]. The proposed inference algorithm for object detection combines the top-down and bottom-up processing for representing and validation of the configuration [28]. Zhuowen, Xiangrong Chen, Alen L Yuille and Son-chun zhu [29] presented a generative/discriminative algorithm that can construct the parsing graph and re-configures it based on Markov principles for object detection, segmentation and recognition.

#### *3.2.1 The probability distribution for the AND/OR graph*

Song Chun zhu and David Mumford [3] provided an exploratory paper for AND/OR graph image parsing. In this paper, we have used the same principle of sketch generation provided in [13] for face localization. The AND/OR graph is represented as a 5-tuple format

$$G_{parse} = ( S, V_N, V_T, R, P) \quad (11)$$

Root node S represents the scene image that includes the face objects and background image (See Fig1).

1. Non-terminal nodes $V_N = V^{AND} \cup V^{OR}$ includes set of AND nodes and a set of OR nodes. Expansion of AND node and selection of OR nodes are guided by Bayesian formulation. (See Fig 2)
2. Terminal nodes or Leaf nodes are set of facial components selected by the certainty factor based feature extraction method and non facial components.
3. R ={ $r_1, r_2, \ldots. r_n$ } describes the pair wise relation defined on the edge between two graph nodes { $v_i, v_j \in V_T \cup V_N$ . } The relations are classified into two categories. In the first category, relation is defined on the AND nodes and OR nodes that they participate maintaining the geometrical configuration. In the second category, relation is defined horizontally on OR nodes keeping the spatial configuration valid. The statistical formulation is used to test the validity of the spatial configuration.
4. P is probability model defined on AND/OR graph structure which uses the Markov Random Field in a Contest free grammar.

The Probability model P stands for stochastic context free grammar (SCFG) which includes Markov Random Field (MRF) in context free grammar environment.

The parse graph is valid traversal of $G_{parse}$ which consists of a set of graph nodes $V = \{v_1, v_2, v_3, .., v_n\}$ and a relation R. The parse graph $p(g_T)$ is a product of probabilities of visited OR nodes $g_T = \{ v_1, v_2, v_3 .. v_n\}$ and the values of the corresponding node switch variables.

$$p(g_T) = \prod_{i=1}^{n} p(r_i) \quad (12)$$

The parsing graph for the face image is shown in the Fig 2. We have used Markov Random Field on each AND node ($A \rightarrow A_i$ and $A_j$) to constrain node attributes and the relation between pair of nodes [8].

$$p(A) = \prod_{i=1}^{n} \phi(X(A_i) \prod_{i=1}^{n} \prod_{j \in N_i} \psi(X(A_i), X(A_j)) \quad (13)$$

The above formulation defines the probability configuration of AND node. The probability model of AND/OR graph is the combination of the probability models for SCFG and an MRF. The prior probability of a graph pg is generated as the distribution that minimizes the Kullback-Liebler divergence between a unknown distribution for some tree structure f(pg) and parse graph tree structure $p(g_T)$. The Entropy distribution method can be used to express the relation between f(pg) and $p(g_T)$.

$$p(pg, \theta) = \frac{1}{Z} \exp(-E(pg)) \quad (14)$$

Where θ = (φ,ψ,α), Z is a partition function.

$$E = \sum_{v \in V} \alpha(W(V)) + \sum_{i=1}^{\mu} \varphi(X(A_i)) + \sum_{i=}^{n} \sum_{j=1}^{n} \Psi(X(A_i), X(A_j)) \quad (15)$$

The first term of the above formulation is the frequencies at each or node and is equivalent to context free grammar. The Second term defines the singleton and third defines pair wise energies defined by MRF probability constraints. Thus the probability of graph p(pg) is equivalent to the probability of its branching tree. The scene is represented by n independent objects and each object is represented by a specific parsing graph $pg_i \in \Sigma$ (G), I=1,2…n. For instance, the scene contains two objects, the graph is $(pg_1,pg_2,G_{bk})$. $G_{bk}$ represents the background image. The face detection is equivalent to calculating the Bayesian probability,

$$fg^* = \arg\max\, p(I \mid \theta) p(G_{bk}) p(N) \prod_{i=1}^{N} p(pg_i, \theta) \quad (16)$$

In the above formulation, N is the number of components detected in the first stage and θ delineates the parameters of the parsing graph. The fg* decides the valid topology of the face in the given image. To implement Recursive top-down/Bottom-up function, we have used two lists of nodes [25].

- OPEN LIST: Nodes that have been generated and the energy values are estimated. It is like Priority queue in which the most promising nodes are included while parsing the image. It contains the nodes that have been generated during bottom up phase
- CLSED LIST: It contains the list of nodes that have verified during Top-Down phase.

Algorithm: Recursive Top-down Bottom Up Image parsing
Input: Input image and selected components by Certainty factor based geometrical extraction method.
Output: Face(s) localized in the Input image.

Begin
Repeat until probabilistic weight is below a threshold
1. Visit the node P

    a. call Bottom-up process to insert nodes into OPEN list without redundancy
    b. Find possible configuration of node P

2. Call Top-down process to update the two data structures.
    a. Accept the evidence from P's OPEN list to the CLOSED list
    b. Remove the evidence from P's CLOSED list and update the OPEN list for nodes that overlap with current node.

End Repeat until
End /* Algorithm */

## IV Experimental Results

The large amount of image material is required for development and evaluation of the face detection system. It is still difficult to obtain an adequate amount of suitable images for specific face detection system. Table I provides the face databases used for the conduction of experiments.

*Table I over view of face database used for detection*

| Name | Number | Color | Size |
|---|---|---|---|
| AR Face database [30] | 3315 | RGB | 768 x 576 |
| Yale Face database[31] | 165 | Grey Scale | 243 x 340 |
| ORL [32] | 400 | Grey Scale | 92 x 112 |
| Image parsing [33] | 3200 | RGB | ----- |
| Georgia [34] | 750 | RGB | 640x480 |

The section 4.1 describes the facial feature extraction and Section 4.2 provides Face localization using image parsing method. Our proposed was implemented with Matlab 7.0.

### 4.1 Facial feature extraction

The CF measure with Bayesian formulation is used to detect the eye blocks. Fig 8 shows the sample of eye images used for training. The window sliding approach is used with window size of 8x8 at the scale factor of 1.5 to measure the Certainty factor. This CF is measure is used to detect the possible eye blocks. Fig 6 shows the accurately detected face components by our method. The Table II shows component accurate locating rate (ALR) of the proposed system. The term Accurate location rate (ALR) means the ratio of the number of images in which eyes are accurately located to the total images used and Average disparity (AD) is the mean distance from the eye position located by the proposed system to that of original eye position in terms of pixels of the image . The advantage of the system is the improvement in computation time compared to the other structural component detection methods. The Accurate locating rate (ALR) of the proposed system is 95% and the Average disparity rate is below 2 pixels. The time required by the proposed system to accurately locate all components of the facial image on Pentium Dual core machine is 1.4s.

*Table II Eye localization by Belief propagation*

| Face Database | ALR | Average disparity (AD) Left Eye Right Eye | |
|---|---|---|---|
| Yale | 94.73 | 1.3 | 0.82 |
| AR | 96.63 | 1.2 | 0.98 |
| ORL | 95.68 | 1.0 | 1.1 |

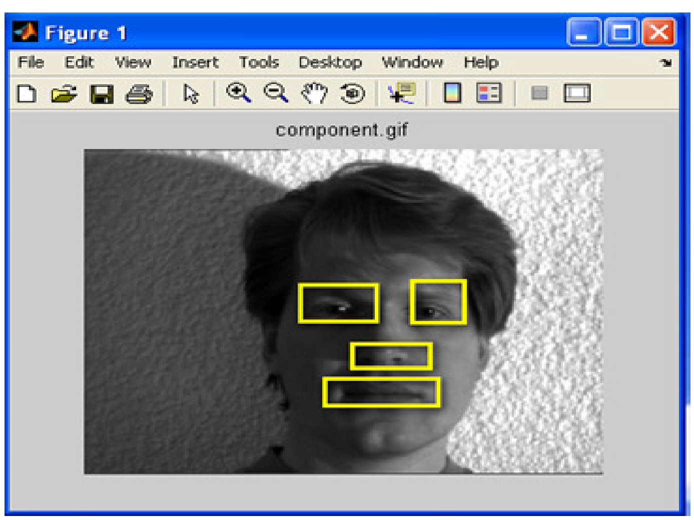


Fig 6 the facial features selected by the detector

### 4.2 Face localization

To verify the proposed system, experiments were conducted on AR, Yale, ORL, Georgia Tech and CMU databases. We have used 165 images from Yale face database, 1657 images from AR face database and 1200 images from image parsing database as positive samples for training. The remaining face images are used for testing. The maximum value of p(pg,θ) is considered as valid topology of the face. The image parsing method accurately localizes the face in the scene image. Fig 7 shows the accurately located face regions on Georgia tech face input image after extracting the facial feature components. In [13], the authors have used the same method for automatic generation of portrait sketch of the human face. We have successfully applied the image parsing to localize the face under Bayes formulation without the annotated images [9]. The detection rate of the system is 93.2 % with false alarm rate of 6. Table III provides the brief comparison of face detection of the proposed system to the other existing efficient Face detection systems.

*Table III Brief comparison of Face detection and false positive rate on CMU database*

| SI NO | Method | Detection rate % | False positives |
|---|---|---|---|
| 1 | Henry A Rowley [35] | 92.5 | 862 |
| 2 | Henry Schneiderman [36] | 93 | 88 |
| 3 | Rainer Lienhart [37] | 82.7 | 10 |
| 4 | Lutz Goldmann [6] | 90.8 | 4 |
| 5 | Proposed method | 93.2 | 6 |

Fig 8 Left and right eye images

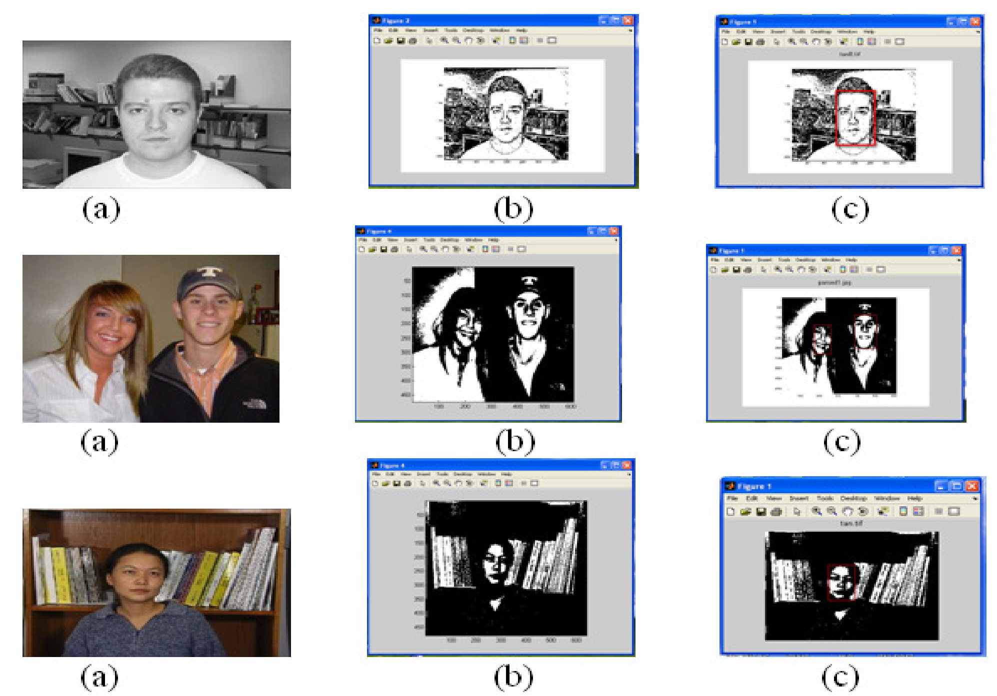

Fig 7 shows the parsing results. (a) Original Image (b) Binary image after boosting (c) Face detected after parsing the binary image

## V Conclusions

This paper presents the computational frame work for image parsing by using the simple visual categories. We have investigated the option of image parsing for face detection in the presence of complex background. The main objective of paper is with representing large visual knowledge in a consistent modeling, and learning for face detection. The Certainty factor based geometrical model accurately detects the facial features of the input image. The other researchers have used the method of randomly selecting the feature block as possible eye features of the face image. We have tested the SCFG with Markov analysis for estimating the topology of the face. This approach is novel for face detection that bridges the gap between appearance and structural models.

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