A Face Detection and Facial Expression Recognition Method

Dr. Nikolaos Bourbakis
ATRC
Wright State University
AIIS
I would like to thank the ICSDT-10 Organizers for the very successful meeting, but especially I would like to thank Professors Tsigritzis and Virvou for inviting me to share some of my views on Face & Facial Expressions with you.
Outline

- Introduction
  - What-why-how
  - Related work
  - Proposed methodology

- Skin color detection

- Face Detection
  - FRG Segmentation
  - Skin Region Synthesis
  - LG Graph

- Facial Expression Detection

- Applications

- Conclusions
Introduction

- What-why-how
- Face detection
- Related work (a brief overview)
- Motivation / Open issues
- Proposed methodology overview
**What**

A method for detecting and recognizing facial expressions in real environment

**Why**

Understanding Human Behavior and Emotions (HHI-HMI)

Security

Surveillance

**How**

- Find skin in real environment using NN
- Detect if the skin regions include faces using LG
- Recognize facial expressions using LG-graph
Face Detection

- **Goal**
  - Detect and locate the face present in the image regardless of
    - Illuminations
    - Background
    - Occlusions
    - Facial pose, orientation and expressions

- **Why is face detection important?**
  - Primary step in
    - Face expression detection
    - Vision-based Intelligent HCI Systems
    - Secure Identification and Authentication
Appearance based approaches

- **Approach**
  - Face is recognized as a whole
  - Face and non-face patterns are learned

- **Limitations**
  - Accurate in frontal images with simple background and in well-illuminations

- **Example - NN Face Detector [Rowley et al., 96, 98]**
Template based approaches

- **Approach**
  - A standard face pattern is pre-defined
  - Use correlation to locate faces

- **Limitations**
  - Difficult to extend to various poses, shapes and scale

- **Example - Active Shape / Appearance Model [Cootes & Taylor, 01]**
Feature based approaches

- **Approach**
  - Detect invariant facial features
  - Group features into candidate faces and verify them

- **Limitations**
  - Difficult to locate features in complex backgrounds and in various illuminations

- **Example - Elastic Bunch Graph [Wiskott et al., 99]**

![Diagram showing Gabor wavelets, jet, image graph, face bunch graph, and grids for face finding.](image)
Multiple Modalities Face-Detection

Open issues

- Current face detection methods [FRVT 2003]
  - Low performance
    - Outdoor images with uncontrolled illuminations
    - Complex backgrounds
    - Non-frontal views

- Realistic, unavoidable conditions!

  * Need a robust method to satisfactorily detect faces in
    * varying illuminations
    * complex backgrounds
The Local-Global Graph Approach

**Overview**

- Skin detection
- L-G graph Face detection
- L-G graph Expression detection

![Diagram showing the process from input RGB image to detected expressions]
Skin-color Adaptation

- ANN method for skin-color adaptation
- Skin detection results
Skin-color

- Skin-color
  - Robust against rotations, scaling and partial occlusions
  - Challenges - ethnicity, Illuminations, background, makeup, motion

Effect of Illumination

- Skin-color varies significantly with different illuminations
- Humans can dynamically adapt to these illumination changes - color constancy

Skin color clusters in normalized $rg$ space
Skin detection approach

Overview [Kakumanu-Bourbakis, ICTAI-04]

- Apply color correction
- Estimate the illuminant
  - Train a neural network to estimate the skin color illuminant
  - Apply color correction in LMS cone space
- Detect skin as the achromatic region
ANN for skin color adaptation

- Multi-layer perceptron network
  - Three layered - $1600 \times 48 \times 8 \times 2$ [Cardei, 00]
  - Input
    - Input $rg$ space is divided into $40 \times 40$ discrete bins
    - Input to the neuron is 1 or 0
  - Output
    - Expected $rg$ chromaticity of the image illuminant

![Diagram showing input image, input color histogram, skin color adapted NN, and illuminant estimate.](image-url)
Skin detection results

Images from UCD Database [Sharma & Reilly, 2003]
+ Images collected at WSU
L-G Graph Face Detection

- FRG Segmentation (smoothing, edge detection segmentation)
- Facial feature region representation
- Region synthesis
- Face LG Graph
- LG Graph matching
- Face detection results
Smoothing is usually considered as an important preprocessing step for a segmentation operation that allows a reduction of the noise within an image. It works as low pass filter by making areas more continuous in their color value. It destructs, however, edges within an image.
Face Detection: Edge Detection

- Edge Detection is the important process that preserves the edges and sharp capes.
- It works as a high pass filter that does not change high frequencies.
Face Detection: Segmentation

- Motivation
  - Skin regions form candidate faces - detect true faces from skin regions

- Identify-extract key features using FRG
  - Apply Fuzzy Region Growing (FRG) Segmentation
    [Moghaddamzadeh- Bourbakis, 1993]
Illustrative Example
: Original, Smoothed, Edged, Segmented
Fuzzy Region Growing (FRG) Segmentation

- Find big and crisp segments.
- Expand segments based on homogeneity criteria.
- Expand segments based on dichromatic reflection model.
- Expand segments based on degree of farness measure.
- Apply an iterative filter.
- Find medium size segments.
- Expand segments using homogeneity criteria and degree of farness.
- Fill in blank regions.
- Apply an iterative filter.
Face detection

- Identify key features
  - Apply Fuzzy Region Growing (FRG) Segmentation
Local Graph

- Local graph [Bourbakis 1987, 2002]
  - Represent the shape by a set of line segments
  - Use local graph to encode spatial relationships

i. The individual properties $P_j$ of line $Ln_j$

\[ P_j = \{ sp(\text{starting point}), l(\text{length}), d'(\text{orientation}), cu(\text{curvature}) \} \]

where the index $j$ indicates the appropriate segment.

ii. The relationships $RL_{ij}$ among the line segments

\[ RL_{ij} = \{ c(\text{connectivity}), p(\text{parallelism}), rd(\text{relative distance}), rm(\text{relative magnitude}), sy(\text{symmetry}), etc \} \]

where, the sub index $ij$ means the relationship between line $i$ and line $j$.

\[
SH = \bigcup \{ Ln_j \cdot R_{j,j+1}^c \cdot Ln_{j+1} \}
\]

\[
= Ln_1 \cdot R_{1,2}^c \cdot Ln_2 \cdot R_{2,3}^c \cdot Ln_3 \cdot R_{3,4}^c \ldots Ln_{n-2} \cdot R_{n-2,n-1}^c \cdot Ln_{n-1} \cdot R_{n-1,n}^c \cdot Ln_n
\]
Chain Coding or Freeman Coding

- Chain coding encodes the position of a pixel not by its actual Cartesian coordinates, but rather by its relative position to an adjoining pixel.
An extended chain code
String

\[ S = k_1(d_1)k_2(d_2)k_3(d_n)\ldots k_r(d_m) \]

where \( d_i \in \{1, 12, 2, 23, 3, \ldots, 78, 8\} \) represent directions, see chain code
and \( k_i \in Z \)

\[ S = L_1 R_{12} L_2 R_{23} L_3 \ldots L_n R_{n1} L_1 \]

where \( L_i \) represents a line segment and \( R_{ij} \) the connectivity relationship with the next line segment \( R_j \)
Line Graph Generation

\[ S = L_1 R_{12} L_2 R_{23} L_3 \ldots L_n R_{n1} L_1 \]

\[ g : L \rightarrow G \]

where \( g(L_i) = N_i \) and \( g(R_{ij}) = a_{ij} \)

\( N_i = \{ \text{sp, orientation, length, curvature} \} \)

\( R_{ij} = \{ \text{connectivity, parallelism, symmetry, etc} \} \)
Local Region graph

Example

Original region

Line fitted region

Region local graph
Region Matching with Wavelets: Geometry Transformation

Single region matching using Wavelets (Yuan-Bourbakis 2002)

A region’s border is represented as

$$f(t) = \begin{bmatrix} x(t) \\ y(t) \\ 1 \end{bmatrix}, \quad t=1,2,...,m$$

The general form of 2-D geometry transformation matrix is

$$\phi = \begin{bmatrix} \phi_{1,1} & \phi_{1,2} & \phi_{1,3} \\ \phi_{2,1} & \phi_{2,2} & \phi_{2,3} \\ 0 & 0 & 1 \end{bmatrix}, \quad \phi = \begin{bmatrix} rs_{xx} & rs_{xy} & trs_{xx} \\ rs_{yx} & rs_{yy} & trs_{yx} \\ 0 & 0 & 1 \end{bmatrix}$$

$$g(t) = S \cdot M_\theta \cdot f(t) + T$$

$$\begin{bmatrix} x'(t) \\ y'(t) \\ 1 \end{bmatrix} = \begin{bmatrix} rs_{xx} & rs_{xy} & trs_{xx} \\ rs_{yx} & rs_{yy} & trs_{yx} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x(t) \\ y(t) \\ 1 \end{bmatrix}$$
Region Matching: Translation

- we set the scale factors to both $x$ and $y$ directions are the same, i.e. $s \equiv s_x \equiv s_y$, thus,

\[
g(t) = s \cdot M_{\theta} \cdot f(t) + T
\]

\[
F_{\text{cen}}(g(t)) = F_{\text{cen}}(s \cdot M_{\theta} \cdot f(t) + T)
\]

\[
= F_{\text{cen}}(s \cdot M_{\theta} \cdot f(t)) + F_{\text{cen}}(T)
\]

\[
= F_{\text{cen}}(f(t)) + T
\]

\[
\Rightarrow \quad T = F_{\text{cen}}(g(t)) - F_{\text{cen}}(f(t))
\]
Region Matching: Scale

- Momentum is a measure of object's mass distribution.

\[ \text{Mom}' = \frac{1}{N} \sum_{i=1}^{N} m_i \cdot \| p_i' - p_{\text{centroid}}' \|^2 \]

\[ = \frac{1}{N} \sum_{i=1}^{N} m_i \cdot \| s \cdot p_i - s \cdot p_{\text{centroid}} \|^2 \]

\[ = s^2 \cdot \frac{1}{N} \sum_{i=1}^{N} m_i \cdot \| p_i - p_{\text{centroid}} \|^2 \]

\[ = s^2 \cdot \text{Mom} \]

\[ \text{Mom} = \frac{1}{N} \sum_{i=1}^{N} m_i \cdot \| p_i - p_{\text{centroid}} \|^2 \]

\[ s = \left( \frac{\text{Mom}'}{\text{Mom}} \right)^{1/2} \]

Scale parameter example
Region Matching: Rotation

The rotate matrix $M$ is defined as

$$M = \begin{bmatrix}
\cos \phi & -\sin \phi \\
\sin \phi & \cos \phi
\end{bmatrix}$$

the rotated curve $f'(t)$ is computed by

$$f'(t) = \begin{bmatrix} x(t)' \\ y(t)' \\ 1 \end{bmatrix} = M \ast f(t) = \begin{bmatrix}
\cos \phi & -\sin \phi & 0 \\
\sin \phi & \cos \phi & 0 \\
0 & 0 & 1
\end{bmatrix} \begin{bmatrix} x(t) \\ y(t) \\ 1 \end{bmatrix}$$

Open problems are
- Rotate angle
- Point correspondence
Region matching: Lips example

- Single region matching using Wavelets (Yuan-Bourbakis 2002)
  - Translation
  - Scaling
  - Rotation

Example of single region matching (model region in blue, object region in red)
Region Synthesis

- Synthesis of regions (Bourbakis 1987)

Motivation
- For face detection, need to identify the key facial regions and their spatial relationships.
- Other regions - not necessary!
Region Synthesis steps

1. **Initialize the first region which is closer to average skin color as the active skin region.** The degree of closeness is calculated as the RGB color difference.

2. **Select the next region which is closer to average skin color.** Find the common edge between this region and the active region.

3. **If a common edge is found, synthesize the current region and the active region.** Assign new region to active region.

4. **If all regions have been processed, region synthesis completes; otherwise go to step 2.**
Region Synthesis

- Skin region synthesis
  - Merge neighbor regions into a single segment
    - Neighborhood region searching based on *skin-color similarity*
  - Find common edge using local graph

\[
L_1 = L_n^1 R_{12}^c L_n^2 R_{23}^c L_n^3 R_{34}^c ... L_n^{n-1} R_{n-1n}^c L_n^c
\]

\[
L_2 = L'^1 n_1 R_{12}^c L'^2 n_2 R_{23}^c L'^3 n_3 R_{34}^c ... L'^{m-1} n_{m-1} R_{m-1m}^c L'^m n_m
\]
Region Synthesis

Relationships among regions

Contiguous

Contain

Contained

Separate

\[
\text{shape}(R_{12}) = \begin{cases} 
\text{shape}(R_1)\text{shape}(R_2), & \text{if } \text{REL}(R_1, R_2) = \text{contiguous} \\
\text{shape}(R_1), & \text{if } \text{REL}(R_1, R_2) = \text{contain} \\
\text{shape}(R_2), & \text{if } \text{REL}(R_1, R_2) = \text{contained} \\
\phi, & \text{if } \text{REL}(R_1, R_2) = \text{separate}
\end{cases}
\]
Skin region synthesis

- Skin region removal or face-lifting
  - Remove skin region - Do not consider it further!
  - Advantage - Simplifies LG graph matching

Skin region synthesis procedure for face lifting for extracting facial features

Skin removal
Global Graph

- The Global graph is a structure that carries inter-region relations. Each node of this graph represents a region, i.e. it contains the respective local graph.

\[
GG(I_P) = (P_1R_{12}P_2)\Phi_{23}(P_1R_{13}P_3)...(P_1R_{1n-1}P_{n-1})\Phi_{n-1n}(P_1R_{1n}P_n)
\]

- The links of this graph represent the relations between regions

Ni

G(A(N1))=(N1R12N2)
\Phi23(N1R13N3)
\Phi34(N1R14N4) ...
\Phi67(N1R17N7)
\Phi78(N1R18N8)\Phi81
Image L-G Graph Comparison

IMAGE -A
Image regions and the graph of gravity

\[ G(A(N_1)) = (N_1R_{12}N_2) \Phi_{23} (N_1R_{13}N_3) \Phi_{34} (N_1R_{14}N_4) \ldots \]
\[ \Phi_{67} (N_1R_{17}N_7) \Phi_{78} (N_1R_{18}N_8) \Phi_{89} (N_1R_{19}N_9) \Phi_{91} \]

IMAGE -B
Image regions and the graph of gravity

\[ G(A(N_1)) = (N_1R_{12}N_2) \Phi_{23} (N_1R_{13}N_3) \Phi_{34} (N_1R_{14}N_4) \ldots \]
\[ \Phi_{67} (N_1R_{17}N_7) \Phi_{78} (N_1R_{18}N_8) \Phi_{89} (N_1R_{19}N_9) \Phi_{91} \]

Comparison A and B
7/8 region relationships same
5/7 angles same
Local-Global (LG) Graph

- Image representation with LG Graph (Bourbakis 1987)

  - Use Delaunay Triangulation
  - Graph edges hold the spatial relationships between facial features
  - Graph nodes hold information about key facial features

\[
\text{node} = \{\text{Centroid}(x, y), \text{color}/\text{texture}, \text{Local} - \text{graph}(L), \text{size}, \text{border}\}
\]

\[
\text{LG} = \{\text{NodeSet}, \text{EdgeSet}\}
\]
LG Graph matching

- Potential Region Correspondent Pair (PCRP)
  - Node correspondence - select regions based on *color similarity*
  - Random graph matching is not allowed!
LG Graph matching

- **Graph similarity - represented by angle**
  - If the correspondent angles between arcs are similar, the graphs are similar
  - Angular similarity

\[
SIM_{LG} = \frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{N} E(i, j) \cdot S_{ANGSIM}(\theta_{ij} - \theta_{i0})
\]

- \( SIM_{LG} \) - similarity between two graphs
- \( N \) - total number of nodes
- \( E(i, j) \) - angle of the edge, \( E(i, j) \)
- \( \theta_{ij} \) - base angle
- \( \theta_{i0} \) - angle similarity function

\[ S_{ANGSIM}(\Delta \theta) \]
LG Graph matching

- PCRP graphs and angular similarity
LG Graph matching

- **LG Graph shape constraint**
  - Nodes are not just fiduciary points!!
  - Use shape from local graph as a similarity constraint

\[
SIM_{LG} = \frac{1}{N} \sum_{i=1}^{N} \sum_{j=1}^{N} E(i, j).S_{\text{ANGSIM}}(\theta_{ij} - \theta_{i0}).\text{Weight}(i, j)
\]

- **LG Graph relationship checking**
  - Relationship similarity \((T_{RE})\) - Contiguous, Contain, Contained, Separate

\[
SIM_{REL} = \prod_{i=1}^{N} \prod_{j=1}^{N} T_{RE}(r_{i,j}, r'_{i,j})
\]

* **LG Graph error**

\[
ERR_{LG} = (1 - ERR_{rel}) \times (ERR_{\text{graph}} + ERR_{\text{shape}})
\]
Experimental results

- LGG matching
Experimental results

- Performance on AR face database [Martinez & Benavante, 1998]

<table>
<thead>
<tr>
<th></th>
<th>Proposed method</th>
<th>Chiang &amp; Huang, 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AR</td>
</tr>
<tr>
<td>Number of faces</td>
<td>240 (30 people * 8 images / person)</td>
<td>945</td>
</tr>
<tr>
<td>Number of correct detections</td>
<td>231</td>
<td>874</td>
</tr>
<tr>
<td>Number of misses/errors</td>
<td>9</td>
<td>14/66</td>
</tr>
<tr>
<td>Recall rate</td>
<td>96.25</td>
<td>92.48</td>
</tr>
</tbody>
</table>

- Limitations
  - Low-image size
  - Poor-image qualities
  - Profile-views (>45°)
  - Dependence on Skin detection method
L-G Graph Expression Recognition

- LG Expression models
- Expression recognition
- Results
Basic facial expressions

- Basic six facial expressions [Ekman, 1993, Kanade et al., 2000]
  - Happy, Surprise, Sad, Anger, Disgust and Fear

- Happy
- Surprise
- Angry
- Disgust
- Sad
- Fear
## LG Expression models

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Happy</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Surprised</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
<tr>
<td>Angry</td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
<td><img src="image16" alt="Image" /></td>
<td><img src="image17" alt="Image" /></td>
<td><img src="image18" alt="Image" /></td>
</tr>
<tr>
<td>Sad</td>
<td><img src="image19" alt="Image" /></td>
<td><img src="image20" alt="Image" /></td>
<td><img src="image21" alt="Image" /></td>
<td><img src="image22" alt="Image" /></td>
<td><img src="image23" alt="Image" /></td>
<td><img src="image24" alt="Image" /></td>
</tr>
<tr>
<td>Disgust</td>
<td><img src="image25" alt="Image" /></td>
<td><img src="image26" alt="Image" /></td>
<td><img src="image27" alt="Image" /></td>
<td><img src="image28" alt="Image" /></td>
<td><img src="image29" alt="Image" /></td>
<td><img src="image30" alt="Image" /></td>
</tr>
<tr>
<td>Fear</td>
<td><img src="image31" alt="Image" /></td>
<td><img src="image32" alt="Image" /></td>
<td><img src="image33" alt="Image" /></td>
<td><img src="image34" alt="Image" /></td>
<td><img src="image35" alt="Image" /></td>
<td><img src="image36" alt="Image" /></td>
</tr>
</tbody>
</table>
Expression recognition

- **Steps in expression recognition [Faisel & Luttin, 2003]**
  - Face detection
  - Feature recognition
    - Nodes in LG graph
  - Expression recognition
    - Construct LG expression graphs

\[
node = \{ \text{Centroid}(x, y), \text{color}/\text{texture}, L, \text{size}, \text{border}, LG_{EXPR1}, \ldots LG_{EXPR_i} \}
\]

- **Features used**
  - Five facial features - eyes, eye-brows, mouth
**LG Expression models [Kakumanu-Bourbakis, in press]**

<table>
<thead>
<tr>
<th>Expressions</th>
<th>Features Considered</th>
<th>EyeBrowL (LGEXPR_EBL)</th>
<th>EyeBrowR (LGEXPR_EBR)</th>
<th>EyeL (LGEXPR_EL)</th>
<th>EyeR (LGEXPR_ER)</th>
<th>Mouth (LGEXPR_M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td></td>
<td><img src="image" alt="Neutral" /></td>
<td><img src="image" alt="Neutral" /></td>
<td><img src="image" alt="Neutral" /></td>
<td><img src="image" alt="Neutral" /></td>
<td><img src="image" alt="Neutral" /></td>
</tr>
<tr>
<td>Happy</td>
<td></td>
<td><img src="image" alt="Happy" /></td>
<td><img src="image" alt="Happy" /></td>
<td><img src="image" alt="Happy" /></td>
<td><img src="image" alt="Happy" /></td>
<td><img src="image" alt="Happy" /></td>
</tr>
<tr>
<td>Angry</td>
<td></td>
<td><img src="image" alt="Angry" /></td>
<td><img src="image" alt="Angry" /></td>
<td><img src="image" alt="Angry" /></td>
<td><img src="image" alt="Angry" /></td>
<td><img src="image" alt="Angry" /></td>
</tr>
<tr>
<td>Scream</td>
<td></td>
<td><img src="image" alt="Scream" /></td>
<td><img src="image" alt="Scream" /></td>
<td><img src="image" alt="Scream" /></td>
<td><img src="image" alt="Scream" /></td>
<td><img src="image" alt="Scream" /></td>
</tr>
</tbody>
</table>
Facial Expression LG graph

- Example

Model in GDB
Facial Expressions

Results

Expression = Angry

- Happy = 0.72
- Sadness = 0.44
- Surprise = 0.77
- Disgust = 0.54
- Fear = 0.52
- Anger = 0.29

Expression = Sad

- Happy = 0.82
- Sadness = 0.34
- Surprise = 0.78
- Disgust = 0.51
- Fear = 0.53
- Anger = 0.59
### Experimental results

- Performance on AR database [Martinez & Benavante, 1998]

<table>
<thead>
<tr>
<th></th>
<th>Neutral</th>
<th>Happy</th>
<th>Angry</th>
<th>Scream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>0.875</td>
<td>0.000</td>
<td>0.125</td>
<td>0.000</td>
</tr>
<tr>
<td>Happy</td>
<td>0.025</td>
<td>0.900</td>
<td>0.025</td>
<td>0.050</td>
</tr>
<tr>
<td>Angry</td>
<td>0.200</td>
<td>0.025</td>
<td>0.775</td>
<td>0.000</td>
</tr>
<tr>
<td>Scream</td>
<td>0.000</td>
<td>0.050</td>
<td>0.000</td>
<td>0.950</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>Happy</td>
<td>Angry</td>
<td>Scream</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>-------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>Expression LG Graph Errors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EyeL</td>
<td>0.72</td>
<td>0.53</td>
<td>0.22</td>
<td>0.26</td>
</tr>
<tr>
<td>EyeR</td>
<td>0.78</td>
<td>0.52</td>
<td>0.27</td>
<td>0.28</td>
</tr>
<tr>
<td>EyeBrowL</td>
<td>0.33</td>
<td>0.34</td>
<td>0.40</td>
<td>0.42</td>
</tr>
<tr>
<td>EyeBrowR</td>
<td>0.37</td>
<td>0.37</td>
<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>Mouth</td>
<td>0.85</td>
<td>0.67</td>
<td>0.82</td>
<td>0.08</td>
</tr>
<tr>
<td>Avg. Error</td>
<td>0.61</td>
<td>0.49</td>
<td>0.42</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Ekfrasis

- Definition: The Ekfrasis language is defined (or generated) by a grammar $G \{V_N, V_T, PR, S\}$,
- where $V_N$, is the set of non-terminal symbols and is defined as $V_N = \{S, T, k, L, X\}$; $V_T$ is the set of terminal symbols and is defined as $V_T = \sum U \{i/i\in\mathbb{Z}, \}$ $U \{\#\}$
- $S$ is the starting symbol of a sentence; $T$ is the symbol for a terminal letter; $L$ is the symbol for the alphabet letters; $\sum$ is the alphabet; $\#$ is the synthesis symbol between letters of the alphabet; and $PR$ is the set of production rules and is defined as
- $PR=\{S \to T; \quad S \to S \# T; \quad T \to L_k; \quad L \to L_1/L_2/L_3/L_4/L_5/L_6; \quad k\in\mathbb{Z}, 1\leq k\leq 6\};$ and $L_i\in\sum$,
- where $\sum = \{EBL_i, EBR_i, EL_i, ER_i, N_i, M_i (UL_i, LL_i)\}$
Language

Definition: The Ekfrasis language (L_EF) is defined over the G grammar as follows:

\[ L_{EF}(G) = \{ \text{Le}_i / \text{Le}_i, \ V_T : S \xrightarrow{G} \text{Le}_i \} \]
Expression recognition (II)

- LG Expression graphs
  - LG expression graphs for each expression to be recognized
  - Expression graph matching

(a) Happy Face Model  
(b) Surprise Face Model  
(c) Sad Face Model
It shows a sequence of facial features (mouth) L-G graphs represent letters from the Ekfrasis language. In this case, individual letters of the alphabet can be used to associate emotional patterns.

It shows the SPN association of the L-G graph of the facial features (mouth) extracted and represented from different image frames, and their activation via token (orange, green color. This case is a sequence of facial expressions related with happiness and laughter). Thus, the color token could be a joke or a happy thought or else.
It shows the transition from the neutral into angry
Token: Voice or Emotion Associated Facial Patterns (mouth). This token triggers the transition from one facial expression into the next.
It graphically shows:

a) The transition from a facial expression (neutral state) into the next facial one (happy state);

b) The order of transitions of facial expressions (from a “state” into another “state”) that take place for the most frequently used facial expressions (neutral, happy, angry, scream);

c) Frames of expressions showing the sequence of transitions in facial expressions.
Biometrics

- Identification & Authentication

ATM Kiosk – Face Verification

Multibiometrics - voice, face, and fingerprint recognition
Applications to People with Disabilities

- Emotional Behavior of People with Disabilities (collaboration with Dr. Esposito, 2003)
- Hearing Impaired Individuals (Koufos project)
- Mentally Retarded Individuals (Anapiros project)
- Visually impaired individuals (Tyflos project)
Summary

Face Detection LG graph Method

LG graph matching

- spatial (graph), shape and relation constraints
- Synthesis of regions
- Compact representation - local (facial features) and global (topology) info
- Invariant to translation, rotation and scale (to an extent)

Facial Expression Detection LG graph Method

Applications
Thank you for your patience

QUESTIONS?