Recognizing Facial Expressions

Lecture-13

Homework, Due November 11

- Lecture 9, slide 17, slide 22
- Lecture 12, page 21 and 22 (three problems).
Program II, Due November 16

• Implement Mean shift Algorithm for tracking
  – Assume that the object location is given in the first frame of the seq
  – Demonstrate your program on known test seqs
  – Demonstrate your program on unknown test seqs in the lab
  – Write a short report: method, problems, results, observations.

Facial expressions reflect the emotional stage of a person.

Recognizing facial expression from video sequences is a challenging problem.

Applications
  – Perceptual user interface
  – Video compression (MPEG-4)
  – Synthesis of facial expressions
Facial Expressions

• Joy
  – The eyebrows are relaxed. The mouth is open, and mouth corners pulled back toward ears.

• Sadness
  – The inner eyebrows are bent upward. The eyes are slightly closed. The mouth is relaxed.

• Anger
  – The inner eyebrows are pulled downward and together. The eyes are wide open. The lips are pressed against each other.

• Fear
  – The eyebrows are raised and pulled together. The inner eyebrows are bent upward. The eyes are tense and alert.

• Disgust
  – The eyebrows and eyelids are relaxed. The upper lip is raised and curled, often asymmetrically.

• Surprise
  – The eyebrows are raised. The upper eyelids are wide open, the lower relaxed. The jaw is open.
FACIAL EXPRESSIONS

RAISE EYE BROWS  SMILE

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FACIAL EXPRESSIONS

DISGUST  ANGER

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Black and Yacoob Algorithm

- Given the location of the face, eyes, brows, and mouth estimate the rigid motion of the face using pseudo perspective motion model.
- Use the face motion to register images through warping.
- Estimate relative motion of face features (eyes, mouth, brows).
- The estimated feature motions are used to predict locations of features in the next frame, and the process is repeated.
- The estimated motion is used to classify the facial expressions.
Affine

\[ u(x, y) = a_1 x + a_2 y + b_1 \]
\[ v(x, y) = a_3 x + a_4 y + b_2 \]

\[
\begin{bmatrix}
 u(x, y) \\
 v(x, y)
\end{bmatrix} =
\begin{bmatrix}
 x & y & 0 & 0 & b_1 \\
 0 & 0 & x & y & 1
\end{bmatrix}
\begin{bmatrix}
 a_1 \\
 a_2 \\
 a_3 \\
 a_4 \\
 b_2
\end{bmatrix}
\]

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Affine

\[ u(x, y) = a_1 x + a_2 y + b_1 \]
\[ v(x, y) = a_3 x + a_4 y + b_2 \]

Expansion or contraction

\[ \text{divergence} = u_x + v_y = a_1 + a_4 \]

Rotation around Z

\[ \text{curl} = -(u_y - v_x) = -(a_2 - a_3) \]

Squashing or stretching

\[ \text{deformation} = (u_x - v_y) = (a_1 - a_4) \]

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Pseudo Perspective

\[ u(x, y) = a_1 + a_2 x + a_3 y + a_4 x^2 + a_5 x y \]
\[ v(x, y) = a_6 + a_7 x + a_8 y + a_4 x y + a_5 y^2 \]

\( a_4 = \text{yaw: rotation around y-axis} \)
\( a_5 = \text{pitch: rotation around x-axis} \)

\[
\begin{bmatrix}
    u(x, y) \\
    v(x, y)
\end{bmatrix} = 
\begin{bmatrix}
    1 & x & x^2 & xy & 0 & 0 & 0 \\
    0 & 0 & xy & x^2 & 1 & x & y
\end{bmatrix} 
\begin{bmatrix}
    a_1 \\
    a_2 \\
    a_3 \\
    a_4 \\
    a_5 \\
    a_6 \\
    a_7 \\
    a_8
\end{bmatrix}
\]
Affine with Curvature

\[ u(x, y) = a_1 x + a_2 y + b_1 \]
\[ v(x, y) = a_3 x + a_4 y + b_2 + cx^2 \]

Rules for Classifying Expressions

• Anger
  – B: inward lowering of brows and mouth contraction
  – E: outward raising of brows and mouth expansion

• Disgust
  – B: mouth horizontal expansion and lowering of brows
  – E: mouth contraction and raising of brows

• Happiness
  – B: upward curving of mouth and expansion or horizontal deformation
  – E: downward curving of mouth and contraction or horizontal deformation
Rules for Classifying Expressions

• Surprise
  – B: raising brows and vertical expansion of mouth
  – E: lowering brows and vertical contraction of mouth

• Sadness
  – B: downward curving of mouth and upward-inward motion in the inner parts of brows
  – E: upward curving of mouth and downward-outward motion in inner parts of brows

• Fear
  – B: expansion of mouth and raising-inwards inner parts of brows
  – E: contraction of mouth and lowering inner parts of brows

Smile Expression

Upward-outward motion of mouth corners results in –ve curvature

Horizontal and overall vertical stretching result in +ve div & def.

Some upward trans is caused by raising of lower and upper lips due to stretching of the mouth (a3 is –ve).
Smile

Figure 6: Smile experiments: facial expression tracking

Smile Mouth Parameters

Figure 7: Smile mouth parameters. The translation, solid and dashed lines indicate horizontal and vertical motion respectively.

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Anger

Figure 10: Anger experiment facial expression tracking, frames every 15 frames.

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Anger Motion Parameters

Figure 11: Anger motion parameters: the solid line indicates the right eye or brow while the dashed line indicates the left eye or brow.
Surprise

Surprise Motion Parameters

[Diagrams showing motion parameters for different facial features like mouth, brows, and eyes, with graphs illustrating trends and changes over time.]
Blinking

Figure 14: Blinking experiment: facial feature tracking. Features every four frames.

Blinking Motion Parameters for Eyes

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Rotation

Rotate Face motion parameters

P₀ rot y
P₁ rot X

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Rotation Motion Parameters

![Graphs showing motion parameters for Mouth and Brows](image)

Table 3: The mid-level predicates derived from deformation and motion parameter estimates.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Threshold</th>
<th>Derived Predicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_0$</td>
<td>&gt; 0.25</td>
<td>Mouth rightward</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.25</td>
<td>Mouth leftward</td>
</tr>
<tr>
<td>$b_0$</td>
<td>&lt; -0.1</td>
<td>Mouth upturned</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.1</td>
<td>Mouth downturned</td>
</tr>
<tr>
<td>$D_{M}$</td>
<td>&gt; 0.07</td>
<td>Mouth expansion</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.02</td>
<td>Mouth constriction</td>
</tr>
<tr>
<td>$D_{M}f$</td>
<td>&gt; 0.005</td>
<td>Mouth front-to-back deformation</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.005</td>
<td>Mouth back-to-front deformation</td>
</tr>
<tr>
<td>$C_{Mef}$</td>
<td>&gt; 0.005</td>
<td>Mouth clockwise rotation</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.005</td>
<td>Mouth counterclockwise rotation</td>
</tr>
<tr>
<td>$c$</td>
<td>&lt; -0.0004</td>
<td>Mouth carving or &quot;X&quot; line</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.0001</td>
<td>Mouth carving downstroke</td>
</tr>
</tbody>
</table>

Mid-level predicates for Mouth

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Mid-level predicates for Head

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Threshold</th>
<th>Derived Predicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_h$</td>
<td>&gt; 0.5</td>
<td>Head rightward</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.5</td>
<td>Head leftward</td>
</tr>
<tr>
<td>$a_n$</td>
<td>&lt; 0.1</td>
<td>Head upward</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.5</td>
<td>Head downward</td>
</tr>
<tr>
<td>$f_{Pr}$</td>
<td>&gt; 0.08</td>
<td>Head opening</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.01</td>
<td>Head contraction</td>
</tr>
<tr>
<td>$f_{Dg}$</td>
<td>&gt; 0.01</td>
<td>Head horizontal deformation</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.01</td>
<td>Head vertical deformation</td>
</tr>
<tr>
<td>$C_d$</td>
<td>&gt; 0.005</td>
<td>Head ocular rotation</td>
</tr>
<tr>
<td></td>
<td>&lt; -0.005</td>
<td>Head move/look/eye rotation</td>
</tr>
<tr>
<td>$p_n$</td>
<td>&lt; -0.0005</td>
<td>Head moving rightward around the neck</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.0005</td>
<td>Head moving leftward around the neck</td>
</tr>
<tr>
<td>$p_r$</td>
<td>&lt; -0.0005</td>
<td>Head moving forward</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.0005</td>
<td>Head moving backward</td>
</tr>
</tbody>
</table>

Parameter values used for classifying expressions
Forty Test Subjects

Results

<table>
<thead>
<tr>
<th>Expression</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surprise</td>
<td>91%</td>
</tr>
<tr>
<td>Happiness</td>
<td>95%</td>
</tr>
<tr>
<td>Anger</td>
<td>90%</td>
</tr>
<tr>
<td>Disgust</td>
<td>93%</td>
</tr>
<tr>
<td>Fear</td>
<td>83%</td>
</tr>
<tr>
<td>Sadness</td>
<td>100%</td>
</tr>
</tbody>
</table>
Beginning of Anger Expression
Frames from 10 Video Clips

Results

<table>
<thead>
<tr>
<th>Expression</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surprise</td>
<td>86%</td>
</tr>
<tr>
<td>Happiness</td>
<td>95%</td>
</tr>
<tr>
<td>Anger</td>
<td>80%</td>
</tr>
<tr>
<td>Disgust</td>
<td>50%</td>
</tr>
<tr>
<td>Fear</td>
<td>100%</td>
</tr>
<tr>
<td>Sadness</td>
<td>60%</td>
</tr>
</tbody>
</table>


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