Computing with Words Model for Emotion Recognition by Facial Expression Analysis Using Interval Type-2 Fuzzy Sets

by

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Topics to be Covered

- What is Fuzzy Word Description?
- Proposed Scheme.
- Merits and Demerits of the Proposed Scheme.
- Used Features.
- Interval Type-2 Fuzzy Membership space Creation.
- Emotion Recognition of an unknown subject.
- Conclusions.
The Problem

Given

- Word Description of 10 Assessor’s about the Features of Facial Expressions of n (=10) subjects carrying a specific emotion.
- No. of emotion classes considered = 5.

Determine

- the emotion of an unknown facial expression from word descriptions only, without providing numerical feature values.
What is Fuzzy Word Description?

- An assessor observes a facial expression and describes the facial features only using the fuzzy linguistic hedges and quantifiers.
- Here the actual measurement of the facial features are not used.

Assessor

Facial Expression of a subject

Opinion of the Assessor about the Facial Expression

- Eye Opening is MEDIUM
- Mouth Opening is VERY LARGE
- Eye-brow constriction is SMALL
Proposed Scheme of Emotion Recognition by Computing with Words Model

Unknown Image

Get numerical value of each feature using the average of the centre of the intervals describing the word description of assessors about that feature

Feature Matching with Fuzzy face Space

Word Description of m (=10) Assessor’s about the Facial Features of Facial Expressions of n (=10) subjects carrying a specific emotion

Interval Type-2 Fuzzy Membership Space, comprising membership function obtained from word descriptions of m assessors about each facial feature

MF selection for different fuzzy linguistic grade

T2FS Rules

Unknown Emotion
Merits and Demerits of the Proposed Model

Merits:

• The proposed scheme does not require absolute measurement of facial features. It only requires word description of the features by a user.
• The proposed method thus saves significant computational overhead required due to pre-processing, segmentation and localization of the facial features.
• Automatic transformation of word description of features into emotions being humanlike, enhances the scope of interaction between humans and machines in the next generation human-computer interface (HCI).

Demerits:

• Lack of precision.
Features Used:
• Left Eye Opening (eo\textsubscript{L}),
• Right Eye Opening (eo\textsubscript{R}),
• Distance between the Lower Eyelid to the Eyebrow for the Left Eye (lee\textsubscript{L}),
• Distance between the Lower Eyelid to Eyebrow for the Right Eye (lee\textsubscript{R}),
• Maximum Mouth opening (mo) including the lower and the upper lips.
• Eye-brow Constriction (ebc)
Creating the Interval Type-2 Fuzzy Membership Space

- Assessors assign different numerical ranges for different linguistic grades for each selected facial feature.

- Assessors also assign one of five grades to the facial features, while examining the facial expressions of different subjects carrying a specific emotion.

- Type-1 Membership Function (MF) for each facial feature for each assessor is now constructed based on the geometric characteristics of the fuzzy quantifiers and the opinion of the assessors about the range of features.

- FOU is constructed then for each feature irrespective of the assessors.

- The FOUs together is referred to as fuzzy membership space.
Opinion of Different Assessors About the Gradations of Feature: MO

TABLE I

<table>
<thead>
<tr>
<th>Assessors</th>
<th>Ranges of each Linguistic Grade</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VS</td>
<td>S</td>
<td>M</td>
<td>L</td>
<td>VL</td>
</tr>
<tr>
<td>1</td>
<td>mo≤7</td>
<td>8≤mo≤10</td>
<td>11≤mo≤13</td>
<td>14≤mo≤18</td>
<td>mo&gt;19</td>
</tr>
<tr>
<td>2</td>
<td>mo≤5</td>
<td>6≤mo≤9</td>
<td>10≤mo≤13</td>
<td>14≤mo≤19</td>
<td>mo&gt;20</td>
</tr>
<tr>
<td>3</td>
<td>mo≤4</td>
<td>5≤mo≤10</td>
<td>11≤mo≤14</td>
<td>15≤mo≤19</td>
<td>mo&gt;20</td>
</tr>
<tr>
<td>4</td>
<td>mo≤8</td>
<td>9≤mo≤13</td>
<td>14≤mo≤16</td>
<td>17≤mo≤20</td>
<td>mo&gt;21</td>
</tr>
<tr>
<td>5</td>
<td>mo≤9</td>
<td>10≤mo≤14</td>
<td>15≤mo≤18</td>
<td>19≤mo≤23</td>
<td>mo&gt;24</td>
</tr>
</tbody>
</table>

VS= VERY SMALL; S= SMALL; M= MODERATE; L= LARGE; VL= VERY LARGE; mo= Mouth Opening.
Opinion of 5 Assessors about a Facial Feature for a particular Emotion and the corresponding Most Likely Grade

Emotion synthesized by Acting

Opinion of 5 Assessors about the Feature mouth opening (mo) for Emotion Happiness

<table>
<thead>
<tr>
<th>Assessor</th>
<th>Mo</th>
<th>Assessor</th>
<th>Mo</th>
<th>Assessor</th>
<th>Mo</th>
<th>Assessor</th>
<th>Mo</th>
<th>Most Likely Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessor1</td>
<td>Mo=VL</td>
<td>Assessor2</td>
<td>Mo= VL</td>
<td>Assessor3</td>
<td>Mo= L</td>
<td>Assessor4</td>
<td>Mo=VL</td>
<td>VL</td>
</tr>
<tr>
<td>Assessor2</td>
<td>Mo= L</td>
<td>Assessor2</td>
<td>Mo= VL</td>
<td>Assessor3</td>
<td>Mo= VL</td>
<td>Assessor4</td>
<td>Mo=VL</td>
<td>VL</td>
</tr>
<tr>
<td>Assessor3</td>
<td>Mo= L</td>
<td>Assessor3</td>
<td>Mo= L</td>
<td>Assessor4</td>
<td>Mo= L</td>
<td>Assessor4</td>
<td>Mo=VL</td>
<td>L</td>
</tr>
<tr>
<td>Assessor4</td>
<td>Mo= VL</td>
<td>Assessor4</td>
<td>Mo=VL</td>
<td>Assessor4</td>
<td>Mo= L</td>
<td>Assessor4</td>
<td>Mo=VL</td>
<td>VL</td>
</tr>
<tr>
<td>Assessor5</td>
<td>Mo= L</td>
<td>Assessor5</td>
<td>Mo= L</td>
<td>Assessor5</td>
<td>Mo= VL</td>
<td>Assessor5</td>
<td>Mo=VL</td>
<td>L</td>
</tr>
</tbody>
</table>
To determine the MFs for fuzzy linguistic grade, we consider two issues:
1) restricting the base of individual MF based on the available range of the feature representing the linguistic grade. (Table I)
2) select a mathematical function to represent the MF, whose parameters are to be tuned intuitively as shown below.

TABLE 2

<table>
<thead>
<tr>
<th>Gradation</th>
<th>Selected MF</th>
<th>Parameter of the MF</th>
</tr>
</thead>
<tbody>
<tr>
<td>VS</td>
<td>exp((-k_1^2,mo))</td>
<td>k_1</td>
</tr>
<tr>
<td>S</td>
<td>e(^{-k,mo})</td>
<td>k_2</td>
</tr>
<tr>
<td>M</td>
<td>e(^{-\frac{(mo-\overline{mo})^2}{\sigma^2}})</td>
<td>\overline{mo}, \sigma^2</td>
</tr>
<tr>
<td>L</td>
<td>1 - e(^{-k_4,mo})</td>
<td>k_3</td>
</tr>
<tr>
<td>VL</td>
<td>1 - e(^{-k_3,mo})</td>
<td>k_4</td>
</tr>
</tbody>
</table>
Illustration of the selection of the parameters of MODERATE MFs According to one Assessor

- From Table I, it can be seen that, $mo$ for MODERATE grade lies in 11 to 13 pixels according to Assessor 1. We set $mo$ as the average of 11 and 13 pixels, i.e. $mo = 12$ Pixels.

- Now, from Table 2, the standard deviation sigma of the mathematical function MODERATE, is evaluated by considering a Gaussian MF for MODERATE grade, and so $mo + 3\sigma$ is approximately equal to 13.5 pixels, yielding $\sigma = 0.5$. 

\[ \mu_{\text{MODERATE}}(mo) \]
Type-1 Membership Function and corresponding FOU Construction for mo: VL and L and Emotion: Happiness

Mouth opening is VL
Memb of happiness

Mouth opening is L
Memb of happiness

Corresponding FOUs

Memb of happiness

Mouth opening is VL

Mouth opening is L

Corresponding FOUs
Emotion recognition of an unknown subject

- Opinion of an user about the features of an unknown facial expression is listed.

- Calculate numerical values of features by considering the average of the centre values of each column of Table I.

- This numerical value of the feature is used to determine the UMF and LMF of the already constructed IT2FS at the pre-determined value of the feature.

- Now take the minimum of the UMFs and LMFs separately and take the average of the resulting minima to obtain the degree of membership of the facial expression to lie in the emotion class $c$ following the Rule. Largest membership of the emotion class is declared as the winner.
Opinion of an user about the features of an unknown facial expression and calculated numerical values of features

- The grade of mo according to an user, is L. The value of the feature mo to be L is the average of the centre value of the 5th column of Table I, i.e., 17.8.

- To evaluate the degree of strength of individual emotions, we now consider four FOUs for the given word descriptions for 5 emotion classes: Anger, Disgust, Fear, Happiness and Fear.

<table>
<thead>
<tr>
<th>Feature</th>
<th>eo\textsubscript{L}</th>
<th>eo\textsubscript{R}</th>
<th>mo</th>
<th>lee\textsubscript{L}</th>
<th>lee\textsubscript{R}</th>
<th>ebc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of the feature</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Numerical value of the feature</td>
<td>12.4</td>
<td>12.4</td>
<td>17.8</td>
<td>20.5</td>
<td>20.5</td>
<td>15</td>
</tr>
</tbody>
</table>
FOUs at the numerical values of features of the unknown facial expression

Emotion = ANGER

Emotion = DISGUST

Feature =
- eo is LARGE
- mo is LARGE
- lee is LARGE
- ebc is LARGE

\[
\begin{array}{c|c|c|c|c}
\text{Emotion} & 12.4 & 17.8 & 20.5 & 15 \\
\hline
\text{ANGER} & \text{MO} & \text{MO} & \text{MO} & \text{MO} \\
\text{DISGUST} & \text{MO} & \text{MO} & \text{MO} & \text{MO} \\
\end{array}
\]
UMFs, LMFs and average of the minima of UMFs and LMFs Obtained from the FOUs

<table>
<thead>
<tr>
<th>Emotions</th>
<th>UMF and LMF of each Facial Feature</th>
<th>Minimum of UMF and LMF</th>
<th>Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>eo</td>
<td>mo</td>
<td>lee</td>
<td>ebc</td>
</tr>
<tr>
<td>ANGER</td>
<td>0.21, 0.79</td>
<td>0.18, 0.61</td>
<td>0.13, 0.7</td>
</tr>
<tr>
<td>DISGUST</td>
<td>0.0056, 0.8011</td>
<td>0.01, 0.45</td>
<td>0, 0.39</td>
</tr>
<tr>
<td>FEAR</td>
<td>0.14, 0.89</td>
<td>0.18, 0.81</td>
<td>0.15, 0.9</td>
</tr>
<tr>
<td>HAPPY</td>
<td>0.21, 0.555</td>
<td>0.673, 0.975</td>
<td>0.1343, 0.8151</td>
</tr>
<tr>
<td>RELAXED</td>
<td>0.21, 0.132</td>
<td>0.14, 0.763</td>
<td>0.013, 0.458</td>
</tr>
</tbody>
</table>

Average has the largest value (≈0.335) for the emotion: fear
So, Emotion of the unknown Facial Expression is Fear
Conclusion

• The paper introduced a word-description model to recognize emotion of subjects from word description about facial features using IT2FS.
• The merit of the work lies in automatic membership function construction from word descriptions and construction of FOUs for each facial feature in different grades for different emotional faces.
• Experimental analysis confirms that the classification accuracy of emotion by employing computing with words model is 87.8%.
Thank You