

Emotion Recognition using Eye Detection and Fuzzy Logic

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# Executive Summary

Our project aims to predict human emotions based on eye behavior. We implemented a fuzzy logic system that took eye behavior features that were classified into different categories as the input, devised a rule set that applied conditions to these classifications and then produced an actual output using rule inference on the input information. We categorized our rules to produce emotions on varying degrees (mild, normal, high). The inputs would be acquired from a hypothetical camera system that could detect changes in eye behavior using image recognition and then aggregate the changes into the categories that we have decided on. The system we developed was able to predict emotions quite well when it received inputs that matched the rule set of normal and high levels of an emotion. The system did not perform as well when discerning between mild levels of emotions. This is due to the necessity of analyzing other facial features to accurately separate milder emotions from one another.

# Problem Representation

We have developed a fuzzy logic system that predicts human emotions as outputs in response to inputs that describe features of eye behavior. We initially aimed to take all forms of facial behavior as inputs but quickly realized the complexity of such a task. Hence this project acts as one of many potential modules of a larger system that uses other facial behaviors (nose, lips, cheeks, jaws, ears) to predict emotions with an even higher accuracy. For this system to be used in a real-world scenario, inputs would have to be received through a prior system beginning with a camera to detect eye behavior and another program that could average the eye behavior into the categories described below.

To begin we broke down eye behavior into 7 different categories, each with their own sets of classifications.

Figure - Output Classifications

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Input | Classification | | | |
| Pupil Dilation | Dilated | Normal | Constricted | - |
| Tears | High | Medium | Low | Dry |
| Rate of Blinking | Rapid | Medium | Slow | - |
| Openness | Squint | Normal | Wide | - |
| Eyebrow Muscles | Up | Normal | Down | - |
| Eye Movement | Rapid | Normal | Slow | - |
| Eye Redness | High | Medium | Low | White |

* Pupil dilation – width of the pupil
* Tears – Amount of wetness in the eyes
* Rate of blinking – number of blinks within a unit of time
* Openness – the amount of the eye that is visible and isn’t covered by the eyelids
* Eyebrow muscles – the position of the eyebrows in relation to the eye
* Eye Movement – The rate at which the eyes move as they look in different directions
* Eye Redness – The color gradient of the eye and the proportion of that which is red compared to white.

The output emotions were ones that we decided could most accurately be depicted by the chosen eye behavior features.

Figure - Emotions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Joy | Sadness | Anger | Anxiety | Confusion |
| Fear | Relief | surprise | Annoyed | Tired |

We then proceeded to define a rule set for the inputs, their classifications, and the expected output. For each emotion, we created one rule to identify the degree of the emotion (mild, normal, high). As we made these rules, we noticed that milder emotions tend to overlap with eye behavior similarities. For these emotions, it is likely that to achieve a higher degree of accuracy, more facial features would need to be included in the final system to create distinct separations of emotion.

Figure - Table of Rules

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Rule Number | Inputs | | | | | | | Output |
| Pupil Dilation | Tears | Rate of Blinking | Openness | Eyebrow Muscles | Eye Movement | Eye Redness | Emotion |
| 1 | Normal | None | X | Normal | Normal | Slow | X | Joy (Mild) |
| 2 | Normal | Low | Slow | Squint | Up | Slow | X | Joy (Normal) |
| 3 | Normal | Low | Slow | Wide | Up | Normal | X | Joy (High) |
| 4 | Dilated | Dry | Slow | Squint | Normal | Slow | Low | Sadness (Mild) |
| 5 | Dilated | Not High | Medium | Squint | Down | Slow | Medium | Sadness (Normal) |
| 6 | Dilated | High | Rapid | Squint | Down | Slow | High | Sadness (High) |
| 7 | Normal | None | Medium | Normal | Normal | Normal | White | Anger (Mild) |
| 8 | Constricted | Low | Medium | Wide | Down | Slow | Low | Anger (Normal) |
| 9 | Constricted | Low | Slow | Wide | Down | Slow | Not Low | Anger (High) |
| 10 | X | Dry | Medium | x | Normal | Slow | Low | Anxiety (Mild) |
| 11 | X | Dry | Medium | x | Down | Normal | Medium | Anxiety (Normal) |
| 12 | X | Low | Rapid | x | Down | Rapid | High | Anxiety (High) |
| 13 | x | x | Medium | Normal | Normal | Normal | x | Confusion (Mild) |
| 14 | x | x | Slow | Normal | Down | Slow | x | Confusion(Normal) |
| 15 | Not Constricted | x | Slow | Squint | Down | Slow | x | Confusion (High) |
| 16 | Normal | x | Medium | X | Normal | Rapid | x | Fear (Mild) |
| 17 | Constricted | Not High | Slow | Normal | Down | Rapid | x | Fear (Normal) |
| 18 | Constricted | High | Slow | Wide | Down | Rapid | Not High | Fear (High) |
| 19 | x | x | Medium | Normal | Normal | Normal | x | Relief (Mild) |
| 20 | x | x | Slow | Normal | Normal | Normal | x | Relief (Normal) |
| 21 | x | Low | Slow | Normal | Up | Normal | x | Relief (High) |
| 22 | Normal | X | Medium | Normal | Normal | x | x | Surprise (Mild) |
| 23 | Dilated | x | Rapid | Wide | Up | x | x | Surprise (Normal) |
| 24 | Dilated | Low | Rapid | Wide | Up | x | x | Surprise (High) |
| 25 | X | Dry | Medium | Normal | Normal | Normal | None | Annoyed (Mild) |
| 26 | X | X | Slow | Squint | Down | Normal | Low | Annoyed (Normal) |
| 27 | X | X | Slow | Squint | Down | Rapid | Medium | Annoyed (High) |
| 28 | Constricted | x | Slow | Squint | Normal | Slow | Low | Tired (Mild) |
| 29 | Constricted | x | Slow | Squint | Down | Slow | Medium | Tired (Normal) |
| 30 | Constricted | x | Slow | Squint | Down | Slow | High | Tired (High) |

The rule set was developed by self-testing, using intuition and research into facial expressions and the emotions that can be seen when just observing the eyes.

# The Algorithm and Data Structures

We used MATLAB Simulink’s Fuzzy Logic Controller with Mamdani fuzzy inference system to implement our logic.

We used membership functions to classify our fuzzy inference system variables (eye behavior inputs) and gave them overlapping parameter ranges.

For example, our membership function and parameter ranges for pupil dilation was implemented like this:

Figure - Pupil Dilation Example (Contricted)

Graphical user interface

Description automatically generated

Constricted – ranged from 0 – 0.4.

Graphical user interface

Description automatically generated

Figure - Pupil Diilation Example (Normal)

Graphical user interface

Description automatically generatedNormal ranged from 0.2 to 0.8.

Figure - Pupil Diilation Example (Dilated)

Dilated ranged from 0.6 – 1.

Graphical user interface, application, Word

Description automatically generatedThe defuzzification method used was the centroid method, where the center of the output was taken as the final emotion. The rules were implemented using AND statements along with their classification categories as shown below:

Figure - Rules

# The Result

Figure - Pupil Dilation

Chart, line chart

Description automatically generated

Figure 1 shows the membership functions and their range for Pupil Dilation.

Figure - Tears

Diagram

Description automatically generated with medium confidence

Figure 2 shows the membership functions and their range for Tears. Dry means there are no tears.

Figure - Rate of Blinking

Chart, line chart

Description automatically generated

Figure 3 shows the membership functions and their range for Rate of Blinking.

Figure - Openness

Chart, line chart

Description automatically generated

Figure 4 shows the membership functions and their range for Openness.

Figure - Eyebrow Muscles

Chart, line chart

Description automatically generated

Figure 5 shows the membership functions and their range for Eyebrow Muscles.

Figure - Eye Movement

Chart, line chart

Description automatically generated

Figure 6 shows the membership functions and their range for Eye Movement.

Figure - Eye Redness

A picture containing diagram

Description automatically generated

Figure 7 shows the membership functions and their range for Eye Redness. White means there is no redness in the eyes.

Figure - Emotion

Chart

Description automatically generated

Figure 8 shows the membership functions and their range for Emotion which is the output. Emotions that are close to each other are placed next to one another (e.g., Relief and Tired)

Figure - Input Example 1

Table

Description automatically generated with medium confidence

Figure 16 is an example that results in the “Joy” emotion (in the output graph, 0.0995 is associated with joy) which has, normal pupil dilation(0.5 – represents a value within the “normal” classification range), low tears, slow rate of blinking, wide eye openness, Eyebrow Muscles that are pointed upwards, Normal eye movement, normal redness (0.5 - doesn’t matter).

Figure - Input Example 2

Graphical user interface, application, table

Description automatically generated

Figure 17 is an example that results in the “Fear” emotion (in the output graph, 0.25 is associated with fear) which has, constricted pupil dilation(0.2 – represents a value within the “Constricted” classification range), medium tears, slow rate of blinking, wide eye openness, Eyebrow Muscles that are pointed downwards, Rapid eye movement, normal redness.

# Program Schematics

Rule Base

Input

Eye features

+

classifications

Output

A 0 or 1 to identify an emotion

AND Statement Rules   
for different outputs

Defuzzification Module (centroid)

Fuzzification  
Module

Mamdani Inference  
Engine

Fuzzy Input (values within parameter ranges)

Fuzzy output (an output value between 0 and 1.

# Code

There is no code for this project, everything was done on Matlab’s Fuzzy Logic Designer and Excel both of which are included with this document.