

Research on the Application of Machine Learning Algorithm and Fuzzy Logic in Eating Assistive Robot



Mubashar Nawaz, Xianhua Li, Sohaib Latif, Sadaf Irshad, Shabnam Sarwar

Abstract: *More than 110 million people in this world are facing some kind of disability, for which they experience difficulty while eating food. Eating Assistive Robots could meet the needs of the elderly and people with upper limb disabilities or dysfunctions in gaining independence in eating. We are researching making a robot, which can assist the disabled in eating their meals. Our Eating Assistive Robot will detect the face of the disabled and process it for whether his/her mouth is opened or closed. Our robot will put a pre-prepared replaceable spoon of food in his/her mouth iteratively until the food lasts in the food container. The methodology we used for it i.e. firstly there is a live camera feed through which we are detecting human faces, after this, a library of Affectiva calculates how much mouth is open. We have set a certain threshold after which the program starts the stepper motor which brings the pre-filled spoon of food into the mouth of the disabled.*

Keywords: *Eating Assistive Robot, Fuzzification, Assistive Feeding, Machine Learning*

I. INTRODUCTION

Eating Assistive Robots should meet the needs of the elderly and people with upper limb disabilities or dysfunctions in gaining independence in eating. We have researched how robots can assist the disabled conveniently in eating. We also have researched Robotics' Components and their integration with developed software. Eventually, we have developed an algorithm using an Affective library that detects a face and calculates how much percent the mouth is opened, and then we have built hardware that performs physical motions.

1.1 Selective Attention

It selects personal designated attention from multiple faces but does not stop or interrupt process information at the same time. It continuously processes the external environment camera feed for searching the human faces and to calculate the attention rate of each face.

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Then decide to whom it should give attention and to whom it should not attend. Attention selectivity and its relevance to goal-oriented behavior have become the most explored areas in western psychology and neuroscience research.

1.1.1 Principle

Motivated by the attention mechanism of humans i.e. how humans pay attention to a specific human, in interaction with multiple humans. We explored various psychological theories, related research papers, and algorithms to understand the human emotional attention mechanism. Then using the Viola-Jones algorithm face detection algorithm, we coded and integrated various units. We can demonstrate that the ac-claimed algorithm working on a video as input for the detection of emotional attention is possible. The results may or may not hold perfect in reality. But still, these results are reliable enough to use for our purpose.

1.2 Attention Dependency Factors Problem

There are a lot of factors on which attention could depend and divert from one to another person like motion, sound, facial expressions, and emotions. Humans normally consider all these factors to give attention e.g. a sudden voice could divert one's attention towards the source of voice or hand motion of a person to other could get his attention.

1.2.1 Solution

"Face is the transmitter of body and eyes are a transmitter of the face."

But in the case of interaction between multiple persons and a robot in specific environment human facial expressions plays an important role in attention diversion from one person to another. This allows us to focus upon face emotions and expressions as reflects the complete human body feelings and interests. Face provides enough information about the state of the individual.

1.2.2 Weakness

The weak point of this solution is that only facial emotions and expressions are being used to detect the attention of an individual. Attention is a vast term and neglecting other attention factors is not less than unfair with an individual. Thus, sound, linguistic, and motion can also be taken as input in future work.

1.3 Face Detection Problem

The Viola-Jones algorithm is not perfect. Its perfection is 90 percent for front faces. Sometimes, faces are detected in walls, chairs, shirts, and other nonfaces likewise.

1.3.1 Solution

First, detect the face Detect Mouth/Lips if the mouth is detected. It's real face else it's a non-human face. Eyes can also be detected to make sure that it's a human face or not. This basic filtering is applied to make things workable and easy.

1.4 Effects Of Changes In Head Angles And Face Luminance

The best performance is in a range of +/- 25 degrees frontal, outside of which accuracy begins to suffer. Furthermore, for the effect of the differences in lighting conditions on the accuracy, the classifier accuracy drops only when the face is extremely poorly illuminated or backlit. This occurs when the average pixel brightness of the face falls below 30 on a scale of 0 (pitch black) to 255 (white).

1.5 Cultural Differences

Many scientific studies demonstrate the universality of facial expressions of emotions; however, each culture employs what we call "display rules"—culturally-specific rules that govern when people amplify, dampen or altogether mask a facial expression of emotion. The research demonstrating the effect of display rules is extensive, covers the past 50 years, and is widely acknowledged. In Southeast Asia there are very clear display rules around how to display emotion, especially in the presence of strangers (a work meeting, a moderator in a research study, etc.): namely, dampen their expressions, especially negative ones.

1.5.1 Solution

The algorithm is trained against a massive emotion data repository consisting of millions of faces that reflect data from 75 countries. This has hardened technology to account for cultural differences with high accuracy.

II. LITERATURE REVIEW

The therapy method is used to provide the robot with a rehabilitation and hand-off process for monitoring, guiding, and helping the post-stroke patients in order of rehabilitation process. This study provides us the opportunity for richer learning and adaptation algorithm[1].The robot navigates continuously the robot's arm activity and helps the patients remembering to copy the rehabilitation program. The second pilot study also described that there is a big relationship between physical embodiment and co-located robots [2].The novel system is designed to provide visually guided active feeding assistance and smoothly put food inside the user's mouth after being visually guided.The system is automatic for feeding patients by using motor impairments [3].A robot is consists of three distinguishing points: handling rice, a meal tray, and a modular design, which is consists of two arms. It can depend on the user's choice that which type of method he wants to chose [4].Brian 2.1 robot is a motivational robot which is used to helping in eating to older persons by its amazing voice and attractions. Many people like this experience and gave positive feedback [5].In 3D visualization, the virtual model is important to understanding the dynamic behavior and the position control of end effectors' position in the operation. The current system depends on the system requirements but can be

changed in a virtual experimental robot [6].The system is based on a PR2 robot which provides a high-level interface by using the web interface to easily use it for people [7].By using this channel, there are three things in this system that are important in future work: User attraction, use of advanced technology, and selection of food items. In previous inquiries, there is the lake of technological work and limitations of selected food items[8].The user's facial expressions method is used to determine the user's demand and desire for those people who are paralyzed. The base-line algorithm is working properly in the face detection method which is currently using most the researchers in commercially available robots[9].The amazing factor is the multiple uses of sensors, which are creating a smooth behavior with nature. This method is enhancing to create a wide functional behavior in a globally accepted systems [10].In our process; Assistive capabilities are included for tangible progress. This system work with motor impairments and is good for bodies users.PR2 robot is used with 2D cursor-based interfaces which provide accessibility for most users [11].The wince method is used for understanding the gestures of a user with a higher vision process. This method has a feasible approach as compare to older methods due to its high accuracy and speedy work [12].Due to an increase in pressure, wiggling has faster penetration. Bite timing is an important to factor which depends on chewing and talking with someone so, adjustment can be made according to user behavior[13].The chosen system depends on a BCI based on the O300 paradigm for the outclass order detection. Software consist of two mainly principle sensors: one is kindest for environment perception and the second is Kenova Jacob for lightweight robot manipulation [14].The developed system is fully friendly of feeding a user by using a spoon and we have chosen multiple food items like rice, peanuts with highly recommended feedback for ensuring that the spoon is full or not [15].We analyzed that people like profound motor deficits for personal use. We used a robot out of the laboratory to serve in the home to settle and serve different tasks with the use of a web browser[16].A multimodal execution monitor has been introduced to assisting a robot for patient feeding. Six baseline methods were used for serving the disabilities[17].For 3D face detection, the setup of the dry electrode EEG system used to determine the patient's brain and the robot was fast, reliable, and has the continuous capacity to deliver stable signals during all process of experiment. Dry-electrode is more efficient as compare to wet-electrode for a long time running and smooth working [18].Discriminative optimization (DO) is a method to solve vision problems by updating the new examples and technology.For the 3D vision factor, we evaluated the potential of DO to solve problems under the rigidity of point cloud registration and proved that it is outperformed state of art approaches [19].For understanding facial behavior, open face source is the best technique in computer vision. Graphical command lines are used to explore the face angle and convert it's indifferent small graphic points for understanding the face expressions[20].

The strategy has two main procedures: sim to real and second is real to sim. The first method is used in simulation as real-world applications and the second method is updating the methods for connecting the simulation with the real world[21]. The robot shows the modular way in fit with research areas properly with different customized methods[22]. ROS-based systems have been used to an enabled an unprecedented level of freedom for enhancing the level of visualization and interaction in the new platform. JavaScript is more valuable programming in this ROS robot with the new standards [23].

III. PROPOSED METHOD

The complete procedure for calculating attention includes steps like face detection and feature detection robot. Detection of the face has been done through C# code. After getting different types of values through the live camera feed, passed these values as input to Matlab fuzzifier. This fuzzifier returns attention numeric value after applying fuzzy logic rules, as output. Then all these values and attention as output are shown in a graph. The library used for detecting face, the promise of providing 34 facial points on a detected human face. The attention through facial expressions decided on the following basis.

3.1 Detection

3.3.1 Face Detection

Face detection is performed using the Viola-Jones face detection algorithm. Landmark detection is then applied to each facial bounding box and 34 landmarks are identified. If the confidence of the landmark detection is below a threshold then the bounding box is ignored. Once a face is detected a boundary box is obtained around it. The boundary bow of the detected face moves with the movement of the face. Detection of faces and localization of the key facial landmarks have been done for each face. Extraction of texture features using HOG. Classification of facial actions

3.3.2 Open Mouth Calculation

This coding was built on the EMFACS emotional facial action coding system. The calculations are given a similar score from 0 (absent) to 100 (present).

3.3.3 Face Size

This face detection algorithm has an additional feature i.e. it can detect both small and large faces.

3.3.4 Multiple Face Detection

Our application has support for detecting faces up to 20 and can extract emotions, to give attention, in case they have head orientation within range.

3.2 Head Orientation It can detect the human face within a specific range of angles. If head orientation is such that it is out of its angle range then it could not able to detect face neither the emotions nor other features. It detects emotions and other facial features with accuracy if the face is within +/- 25 degree angle.

3.3 Brightness

It works in a certain amount of light and when light intensity is below a certain threshold then it is not able to detect faces within the camera frame.

IV. FUZZIFICATION

The modern-day technologies in the areas of information storage and retrieval, web search, image processing, control, pattern recognition, bio information and computational biology, e-markets, autonomous navigation, and guidance are benefited using the fuzzy logic systems. Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision-making in humans that involves all intermediate possibilities between digital values YES and NO.

The process of fuzzification is of great importance for getting the required results. As described in the above section, calculation of attention has been done through fuzzy logic. We have used this in such a way that, two largest emotions numeric values (out of six emotions) of a human face, identified through a function used as input to the fuzzy logic system. For these two inputs, 25 rules have been written to get the required output as attention. Using these rules we get attention as output. Furthermore, dot net (.net) library has been made in Matlab, for further processing.

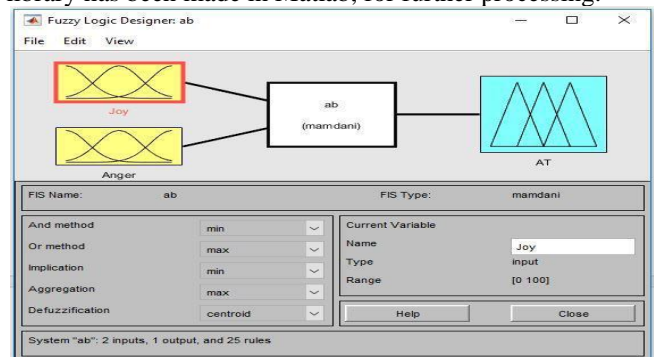


Figure 3.1: Fuzzy System for Attention

In figure 3.1 the abstract model of fuzzy inference system for calculating attention from the two largest emotions values of the detected human face has shown. One can see clearly from the figure that two emotion values are using here as input namely joy and anger and these values passed further. After applying Mamdani fuzzy rules to these inputs attention we get as output. Here in our scenario, the attention levels have been calculated through a fuzzy inference system, where the inputs, outputs, and there ranges for varying linguistic values are as under:

Joy = {"Very Low", "Low", "Medium", "High", "Very High"} [0, 1]
 Anger = {"Very Low", "Low", "Medium", "High", "Very High"} [0, 1]
 Direct_Attention = {"Very Low", "Low", "Medium", "High", "Very High"} [0, 1]

3.2: Ranges for Fuzzy Inference System for calculating weights of direct attention In the above figure, 3.2 mentioned dimensions are arranged for all possible combinations to construct rules for Inference Engine. The possible rules fed to the fuzzy system are written in Matlab.

4.1 Membership Function

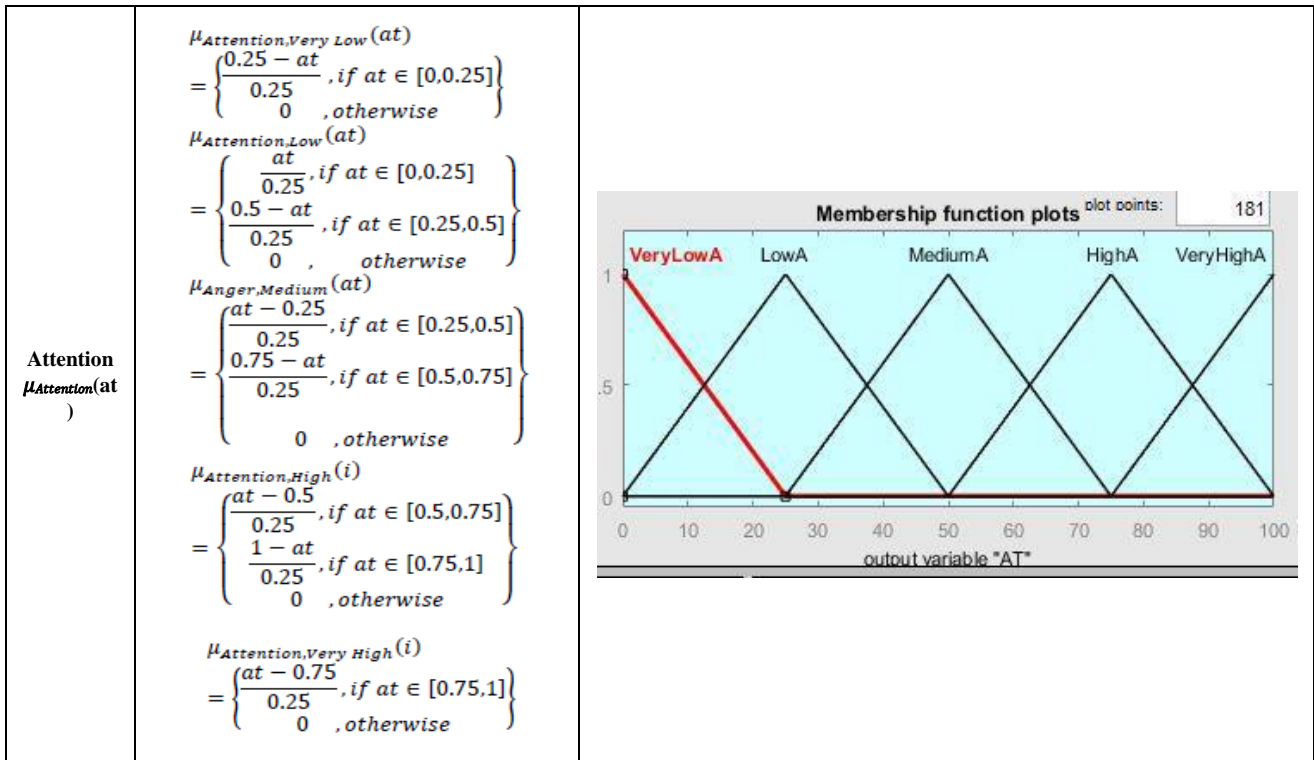
A membership function (MF) is a curve that defines in figure 3.3 how each point in the input space (also called the universe of discourse) is mapped to a membership value (or

degree of membership) between 0 and 1.

$$\mu_{A \cap I \cap B \cap S}(x) = \min[\mu_A(x), \mu_I(x), \mu_B(x), \mu_S(x)]$$

Figure 3.3: Mathematical & Graphical MF of Layer-1 Emotional Attention-Fuzzy Inference System Input variables

Input	Membership Function	Sample MF Screenshot
<p>Joy $\mu_{Joy}(a)$</p>	$\mu_{Joy,very\ Low}(a) = \begin{cases} \frac{0.25 - a}{0.25}, & \text{if } a \in [0,0.25] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Joy,Low}(a) = \begin{cases} \frac{a}{0.25}, & \text{if } a \in [0,0.25] \\ \frac{0.5 - a}{0.25}, & \text{if } a \in [0.25,0.5] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Joy,Medium}(a) = \begin{cases} \frac{a - 0.25}{0.25}, & \text{if } a \in [0.25,0.5] \\ \frac{0.75 - a}{0.25}, & \text{if } a \in [0.5,0.75] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Joy,High}(a) = \begin{cases} \frac{a - 0.5}{0.25}, & \text{if } a \in [0.5,0.75] \\ \frac{1 - a}{0.25}, & \text{if } a \in [0.75,1] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Joy,very\ High}(a) = \begin{cases} \frac{a - 0.75}{0.25}, & \text{if } a \in [0.75,1] \\ 0, & \text{otherwise} \end{cases}$	
<p>Anger $\mu_{Anger}(i)$</p>	$\mu_{Anger,very\ Low}(a) = \begin{cases} \frac{0.25 - i}{0.25}, & \text{if } i \in [0,0.25] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Anger,Low}(i) = \begin{cases} \frac{i}{0.25}, & \text{if } i \in [0,0.25] \\ \frac{0.5 - i}{0.25}, & \text{if } i \in [0.25,0.5] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Anger,Medium}(i) = \begin{cases} \frac{i - 0.25}{0.25}, & \text{if } i \in [0.25,0.5] \\ \frac{0.75 - i}{0.25}, & \text{if } i \in [0.5,0.75] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Anger,High}(i) = \begin{cases} \frac{i - 0.5}{0.25}, & \text{if } i \in [0.5,0.75] \\ \frac{1 - i}{0.25}, & \text{if } i \in [0.75,1] \\ 0, & \text{otherwise} \end{cases}$ $\mu_{Anger,very\ High}(i) = \begin{cases} \frac{i - 0.75}{0.25}, & \text{if } i \in [0.75,1] \\ 0, & \text{otherwise} \end{cases}$	



4.2 Defuzzification

To check the correctness of rules written in Mamdani fuzzy inference system for calculating attention, the process of defuzzification in contrast to fuzzification has been applied. After applying all mathematical equations and expressions the error rate we get is only 6%, which shows the correctness of Mamdani fuzzy rules.

V. EXPERIMENTATION AND RESULTS

5.1 Single Face Detection

The testing data contains sets, each set having the face of a human. The face is detected from 34 points on a human face.

5.2 Multiple Face Detection

Detection of faces is not limited to only one face rather the application can detect more than two faces.

This shows the robustness in the application. The criteria for detecting face is that it can detect a face in live camera feed through 34 points on the face.

5.3 Various Emotions On Face

Once a face is detected, emotions on that face showing in the form of a graph. The various emotions of a person respectively change on the graph too. The emotion on the face is said to be joy, anger, disgust, etc. This categorization helps to define the attention.

5.4 Attention To A Face

Once multiple faces are detected through the live camera feed, the attention algorithm will decide to whom attention should be given. For Example, 3 faces detected through live camera feed, 2 faces have normal emotions but one face has a superb value of joy then the attention algorithm will make a red square around that face showing the sign of attention. As different persons have different levels of emotions, so

this attention might be moved to another person if he/she will show extraordinary emotion.

5.5 Attention On A Graph

Every face has an attention rate according to the emotions on its face. The attention rate for a specific face is calculated using Fuzzy Logic as discussed in the above chapters. This attention rate is showing in the form of a graph. If there are two faces in the camera frame, each face has its graph associated with it. The graph is showing all emotions' continuous values along with continuous attention vale for each face. As emotions are detecting through live camera feed, the attention values for making a graph are continuous.

VI. CONCLUSION

The initial motive was to develop a complete system i.e. Hardware plus Software along with a machine learning algorithm. Also to create human-like attention based on emotions, as humans pay attention based on emotions, in robots. Based on machine learning algorithms, the robot can pay desired attention in real-time. After giving Attention the robot calculates the percentage of mouth opened and then feeds the disabled accordingly. The individual attention module has been completed. Both for single face and multiple faces, the attention criteria is the same. The attention module is working on a video (live camera feed) as input and gives an output graph showing values of emotions and attention for each face detected in the live camera feed. Calculating the percentage of opened mouth is the baseline of this project and all the information that can be derived from face has been covered like open eyes, brightness, head orientation and all emotions (joy, anger, sadness, disgust, surprise, and fear) are the salient features from face and its near environment. Attention graph is being maintained for every person in the video frame.

7. Future Work

Make hardware flexible enough that the robot can adjust itself according to the height of the disabled.

The robot can be made to target the mouth of the disabled to feed him/her. Such motion can be introduced as the disabled falls forward, the robot moves backward, and vice versa. Addition of the mechanism to provide the ease of drinking water can be made. A robot can be made to handle variable distances while feeding.

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