Automated Fuzzy Detection System for Efficient Pedestrian Detection in Traffic Areas

Abstract— Fuzzy inference systems have been successfully applied in different fields such as automatic control, data classification, decision analysis, expert system, and computer vision. In this paper, fuzzy inference models have been developed to reveal traffic situations and behavior in some highway locations. This approach uses fuzzy logic systems with knowledge-based analysis by defining some useful linguistic variables and appropriate membership functions for mapping the input parameters for efficient traffic congestion. Pedestrian traffic flow and density have been used as input data for the fuzzy inference model while the output after defuzzification process comes in the form of detected pedestrian levels with various range of membership values. The experimental results demonstrated that fuzzy inference models could be effectively used for pedestrian detection in transportation system.

Index Terms— Fuzzy Inference, Pedestrian detection, Traffic flow, Defuzzification Process Fuzzification Process, Expert System, Density, Fuzzy logic system.

1 Introduction

Fuzzy inference systems have been successfully applied in different fields such as automatic control, data classification, decision analysis, expert system, and computer vision. Because of its flexibility, Fuzzy inference systems are associated with a number of names like fuzzy-rule based systems, fuzzy expert systems, fuzzy modeling, fuzzy logic controllers and fuzzy systems. There are two different ways by which Fuzzy inference systems can be developed. Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Fuzzy inference system can also be used as an attempt to control a steam engine and boiler combination for producing a set of linguistic control rules obtained from human operators. His approach was based on fuzzy algorithms for complex systems and decision processes. The paper in [1]-[2] described models to synthesize the evolution of fuzzy of the features identified during clustering to develop an appropriate Fuzzy Inference System (FIS). FIS will then act as a relation and partitions for the selection of useful features, clustering of data, and accurate classification. In their research, it was concluded that the developed system could be effectively applied to real physical problems with measurable success.

Fuzzy logic is an effective method to address the problem of imprecision. It could be used to take fuzzy or imprecise observations for inputs and yet arrive at precise values for outputs. Fuzzy logic can be employed to capture the broad categories model that will reflect the relationship between input and output variables in the data set. Therefore, clustering can be a very effective technique to detect natural groupings in data from a large data set, and eventually allowing accurate representation of relationship embedded in the data. This approach could be used to group the pedestrians' features and effectively applied to build Fuzzy logic systems for accurate detection and classification of the moving objects. How can we determine the appropriate membership function for the pedestrian features using the fuzzy logic? What is the ability of the generated Fuzzy inference system in terms of detecting the moving objects? Can the Fuzzy reasoning rules be effectively used for constructing a robust model? How can we determine the performances of the model in terms of recognition accuracy and other important parameters? These research questions would be very useful in the development of the system in detecting any moving objects in traffic areas. The list of if-then statement is the most common approach in fuzzy logic to map an input space to an output space called rules. However, the ordering of the rules is not important but all rules are evaluated in parallel. The rules are the primary mechanism for achieving our goals in this research as they are very useful because they refer to variables and the adjectives that describe those variables. Few researchers have done some related work in this area but the uniqueness of this research work is that the constructed models should be able to outperform the existing systems in terms of space and time complexities, and the overall computational efficiency. The goal of this research work is to identify the key elements of fuzzy pedestrians in traffic areas and applied these components for accurate recognition. This work will also help to describe and analyze fuzzy models that could be effectively used to improve the recognition rate. However, why fuzzy pattern recognition in pedestrian detection? This is a very important research question that must be properly answered. The keyword combinations of “fuzzy” plus clustering or classification have yielded useful results in the previous work. The literature contains a large body of work on fuzzy clustering and classifier design but not much work has been done so far in fuzzy models for feature analysis.

The importance of fuzzy models in pattern recognition can be determined in different application areas such as chemistry, Electrical Engineering, Geology/Geography, Medicine, Physics and Environmental Sciences. This paper would therefore provide an improved approach using the combination of two different ideas; that is the fuzzy clustering would be combined with the appropriate fuzzy models in feature analysis by using fusion or hybrid technique methods for decision-making in classification and evaluation of features extracted from the object data. The reasons for using this technique would be better explained in the following section since it has been discovered in the literature that both approaches have some limitations. This paper would apply this fusion technique to address some of the problems in the existing system to develop a new system that could improve and yield better results. [3] applied different fuzzy techniques to deal with complex and ambiguously defined systems in the analysis of data. In his research work, some of the basic steps in recognition systems such as pre-processing, feature extraction, classifier design and optimization were investigated. [2] presents different fuzzy C-means algorithms for analyzing medical images. Experimental analyses were performed with some standard data to identify the region of interest and remove noise and outliers in the images. The experimental results showed that this paper could be very useful to determine the appropriate fuzzy clustering method or the most suitable approach for research work. The fuzzy c- means technique developed by [8] was applied for data clustering while Euclidean distance has been successfully used to obtain the membership values. For comparison purposes, other distances like Hamming distance, Canberra distance were also tested with different experiments using different clusters.

Pedestrian detection is also a very serious problem in the field of computer vision; it has applications in areas like surveillance, automotive safety and robotics [4]. It was discovered that most of the previous work in the area of pedestrian detection has been facing the problem of appropriate public datasets for quality research work. This is understandable since it is difficult to capture and store different objects in motion. [8] developed a novel model that combines global and local features to address the problem of detecting pedestrians in crowded scenes with severe overlaps. The results showed that the developed methods can be reliably used to detect pedestrians in crowded scenes. The authors in [4] present a two-step approach for object detection; the first step uses contour features from hierarchical template as a matching approach to proffer solutions to detection problems. The second step utilizes the intensity features in a pattern classification approach to verify the candidate solutions. K means clustering has been used in [15] for early detection of cancer in the breast, the authors stressed further to demonstrate the effectiveness of thermography in cancer detection. This method uses thermal and vascular conditions to extract powerful features from images unlike other methods with structural properties for efficient detection and analysis of cancer. The impact of deep learning in machine learning for identifying nodules in CT images have been successfully demonstrated in health informatics [3]-[5]. The authors have applied this emerging method (deep learning algorithm) for automatic extraction of features in the analysis of patients or patterns with certain diseases for health monitoring and diagnoses [3],[5]-[7]. The effects, performances and applications of deep learning models were thoroughly investigated in bioinformatics, medical imaging, pervasive sensing, medical informatics and public health [5]-[7]. [9] presents a state of the art general model for efficient detection and analysis of pedestrian objects using INRIA datasets; their methods used the feature resolutions of the detected objects to improve the existing results. The experiment achieves good results with a small precision gap from the state of the art method in terms of speed and accuracy on the datasets in pedestrian detection. The model uses a scaling property of the image structure to make progress in correcting the errors on the Caltech dataset. In [18], the authors introduced a multispectral method as an extension of aggregated channel features (ACF) for improving the results in pedestrian detection. The results showed his approach significantly reduced the average miss-rate by 15%, which led to great improvement in pedestrian detection tasks. It was also discovered that the multispectral images could be very useful in solving pedestrian detection problems such that the proposed dataset can provide better pedestrian detection region of interest and remove noise and outliers in the images.

The authors in [7] propose a density-based fuzzy c-means (D-FCM) algorithm to determine the number of clusters and initial membership matrix for image segmentation, the results show that the developed method compared favourably with ordinary FCM as it demonstrates an increase in accuracy and effective reduction in the number of clustering iterations.

This paper [10] proposes an improved metric method to address this challenge and provides several promising detection systems that are comparable with the existing systems. Object detections on the highways could sometimes become a very serious problem since there could be so many things going on in the atmosphere at a time. Recently, in the last two years, there has been interest in pedestrian detection using different methods in the field of computer vision. The most important of all the applications is the automotive applications since it has the potential to save numerous lives. Some of the uniqueness of our work is that pedestrian detection as we have explained is very new, another important point here is that no researcher has ever applied fuzzy logic to address the problems of pedestrian detection in traffic areas. This is very interesting because this idea would help us to develop new models that would extract the useful features in the pedestrian datasets to improve the detection accuracy and computational efficiency. Again, this could possibly be a very good contribution since most of the existing algorithms in Fuzzy logic have one problem or the other in this research area. Moreover, existing pedestrian datasets have limited range of scale, different appearance and pose variation [11]- [14], making the computational accuracy to be very difficult and access to real life data could be a very serious challenge since capturing objects in motion might be time and memory consuming. The state-of-the-art method for pedestrian detections, which uses per-window approach is flawed and can sometimes fail to predict the actual performance [15]-[17].

2 METHOD FOR COMPUTING FUZZY INFERENCE SYSTEM

The theory of Fuzzy logic is based on a principle that the important elements of human thinking are not numbers but rather labels of fuzzy sets. On the other hands, the occurrence of uncertainty in human thought indicates that much of the logic behind human reasoning is not the traditional two or multi-valued logic, but a logic with fuzzy truths, fuzzy connectives and fuzzy rules of inference [19]-[21]. Therefore, fuzzy logic, fuzzy sets and fuzzy inference methods provide means for the manipulation of uncertain and imprecise concepts. We can formalize these by stating Y to be a non-empty set. A fuzzy set B in Y is characterized by its membership function: $\mu B: Y \rightarrow [0, 1]$ and $\mu B(y)$ can be interpreted as the degree of membership of element y in fuzzy set B for each $y \in Y$. The degree at which the statement 'y is B' is true can be defined as the degree of membership of y in B. The process of transforming the system inputs, which are crisp numbers into fuzzy sets, is called fuzzification Module while defuzzification module transforms the fuzzy set created by the inference engine into a crisp value. The knowledge base for the fuzzy logic system stores IF-THEN rules provided by experts to process the fuzzy sets. The inference engine simulates human reasoning process by deducing fuzzy inference on the fuzzy input sets from fuzzification module combined with IF-THEN rules from the knowledge base to process the fuzzy output set (Figure 1).

The term that can be used to define if the elements of input space belong or not belong to a particular set and which degree of membership do they belong is called membership function. This can be achieved by assigning each element of the input variable with the corresponding membership value in a closed unit interval [0-1]. Five different shapes that could be generally used to represent a membership function are: Gaussian, bell, sigmoidal, trapezoidal and triangular. The implementation of input variables and membership function values could be used to generate models for solving problems in computer vision.

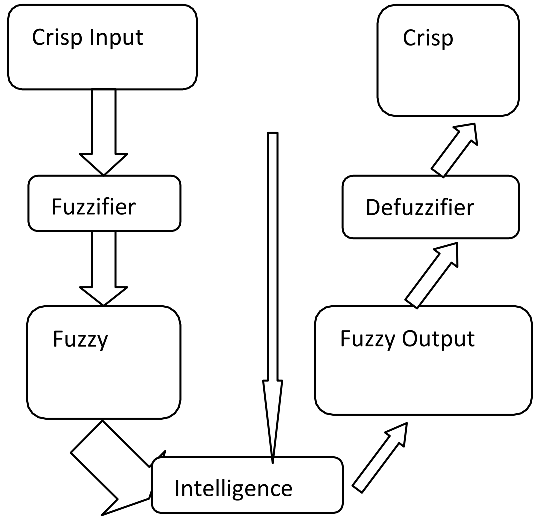

Figure: 1. Implementation of Fuzzy logic system on Fuzzy sets of variables

Fuzzy inference engine has the ability to effectively use the information from the knowledge base and that of input variables to generate excellent results. The process itself involves several phases as we have previously discussed.

The fuzzy logic system has four major parts as shown in Figure 1, the fuzzification module, which transforms the system inputs of crisp numbers to fuzzy sets by splitting the input signal into five steps is the first step in this process. In this research, the two input variables that would be implemented for developing a fuzzy inference model are the pedestrian flow and density while the output parameter is level of pedestrian (lop). Flow refers to the number of vehicles that pass through the city within a certain period of time; in our data, we have got five lanes. Density represents the number of pedestrians passing through specific location in terms of longitude and latitude on the highways within that direction in every 60 seconds. How do we now calculate the density? The traffic density can be calculated using datasets to measure the number of pedestrians crossing the highways in a certain period. Let's assume vehicles are of equal length, the relationship between relative occupancy (V) and density (D) can be calculated as follows:

$$V = L*D \tag{1}$$

Where L is the length of vehicles across the highways in those locations of concern. The two input variables and one output would be fuzzified to generate many membership functions. Membership functions allow you to quantify linguistic terms and represent a fuzzy set graphically. Each element of X is mapped to a value between 0 and 1. The degree of membership of the element in X is quantified to the fuzzy set A. X-axis represents the universe of discourse, while y-axis represents the degrees of membership in the [0, 1] interval. In this research, the traffic density can be divided into five parameters such as: Very Low Density (VLD), Low Density (LD), Medium Density (MD), High Density (HD), and Very High Density (VHD). For the pedestrian flow input variable, this can be divided into Free Flow, Reasonably Free Flow, Stable Flow, Unstable Flow, Near-congestion Flow and Congested Flow. There can be numerous membership functions applicable to fuzzify these input variables but the membership functions to fuzzify the traffic density are shown in Figure 2 below.

In the fuzzy inference process, it is important to establish a system, which indicates how to project input variables onto output space. This can be achieved by specifying if-then fuzzy rules. A single fuzzy if-then rule follows the form:

$$\text{If } k \text{ is } A, \text{ Then } m \text{ is } B \tag{2}$$

Where k is input variable and m is output variable. Both A and B are linguistic values that enable this form of conditional statement to work in line with human decisions. The most common operators that can be used to combine these membership values are AND and OR operators. These operators apply function max and min to join membership values together to obtain fuzzy values.

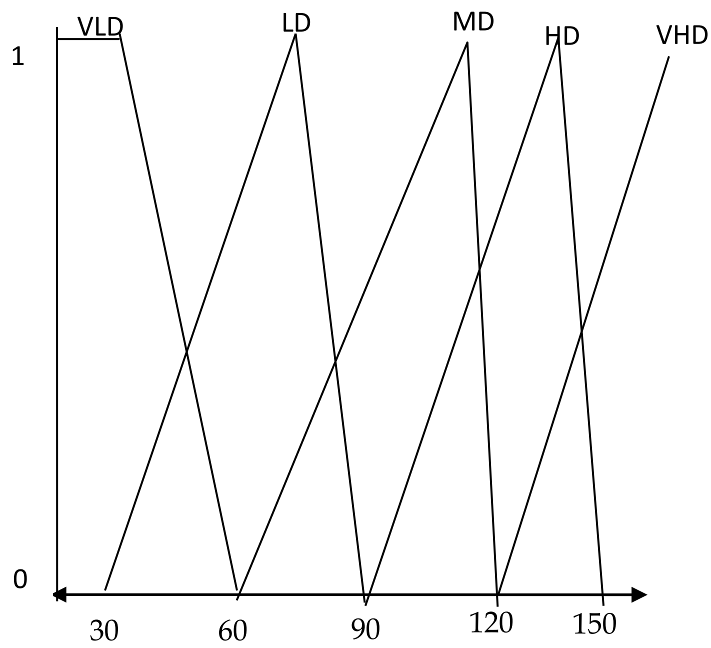

Figure. 2. Triangular membership function for traffic density fuzzifier

3 RESULTS AND DISCUSSION

The first thing is to build an inference model with the input and output variables as outlined in the previous section. The two input variables are pedestrian flow and density while the output variable is level of the pedestrian. The second step is to fuzzify the input and output parameters by assigning five membership functions to them. For instance, the linguistic variables for the input parameter; flow are free pedestrian flow, reasonably free pedestrian flow, stable pedestrian flow, unstable pedestrian flow and congested pedestrian flow while linguistic variables: Very Low Density, Low Density, Medium Density, High Density, and Very High Density. The level of pedestrian, which is the output parameter, is then calculated for each road segment to determine the performance of pedestrian model for the detection. Additionally, the information from the fuzzified inputs are then combined using the if-then rules and the linguistic variables are connected using AND operator. Table 1 shows the interpretation of each level of pedestrian.

Table 1: Fuzzy inference model output parameter (level of pedestrian)

LOP1	Completely Pedestrian free
LOP2	Reasonable Pedestrian free
LOP3	Stable Pedestrian free
LOP4	Unstable Pedestrian free
LOP5	Congestion

In order to derive decision from the chains of rules by the output parameters, we need to further combine the features using the If-then rules with AND operator, this process of aggregation is known as de-fuzzification as presented in Table 2.

Table 2: Fuzzy If-then rules with AND Operator

IF	AND	THEN
Flow is free flow	Density is very low	LOP is LOP1
Flow is free flow	Density is very low	LOP is LOP2
Flow is stable flow	Density is low	LOP is LOP3
Flow is unstable flow	Density is high	LOP is LOP4
Flow is congested	Density is very high	LOP is LOP5

Lastly, we ran the model to determine the results of different routes to observe traffic behaviour for different experiments that we have put into consideration. The results would help us to know how busy the road is since the closer the value to zero. The less congested the road is and vice versa, the closer the value to 1, the more congested it gets. The results present in Table 3 show the traffic behavior of the highway for the region considered.

Table 3: Fuzzy inference model input variables (flow and density) and output variable (level of pedestrian)

Flow	*Density*	*Level of Pedestrian*
15	*19.5*	*0.61*
19	*45.6*	*0.95*
17	*41.4*	*0.88*
12	*85.2*	*0.54*
8	*102.4*	*0.36*

In Table 3, the levels of pedestrian are very close to one another, the density input ranges from 19.5 to 102.4; when the flow is 19, the level of congestion closes to 1(0.95), which indicates severe congestion area but when the flow is 8 the level of congestion reduces to 0.36, which indicates congestion-free zones. The closer the congestion to 1 the higher the traffic in that location while the closer the congestion to zero, the less the traffic in that location.

4 CONCLUSIONS

The traffic density and flow traffic have been calculated to determine the behaviour of traffic in those regions of consideration. All vehicles are assumed to be of the same length even though they are not really of the same length. This factor can introduce error into our experimental computation as part of the limitation in this research. The results have shown that the total flow on the region of interest is about 5000 vehicles per hour but we assume that the capacity of each road is around 1500 vehicles per hour in a less congested area. Additionally, some if-then rules have been specified arbitrarily to combine information from input parameters that would result in fuzzy values. The proposed method is simple as it applies and follows common logic. The developed model has been very effective in modeling traffic behavior and transportation process.

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