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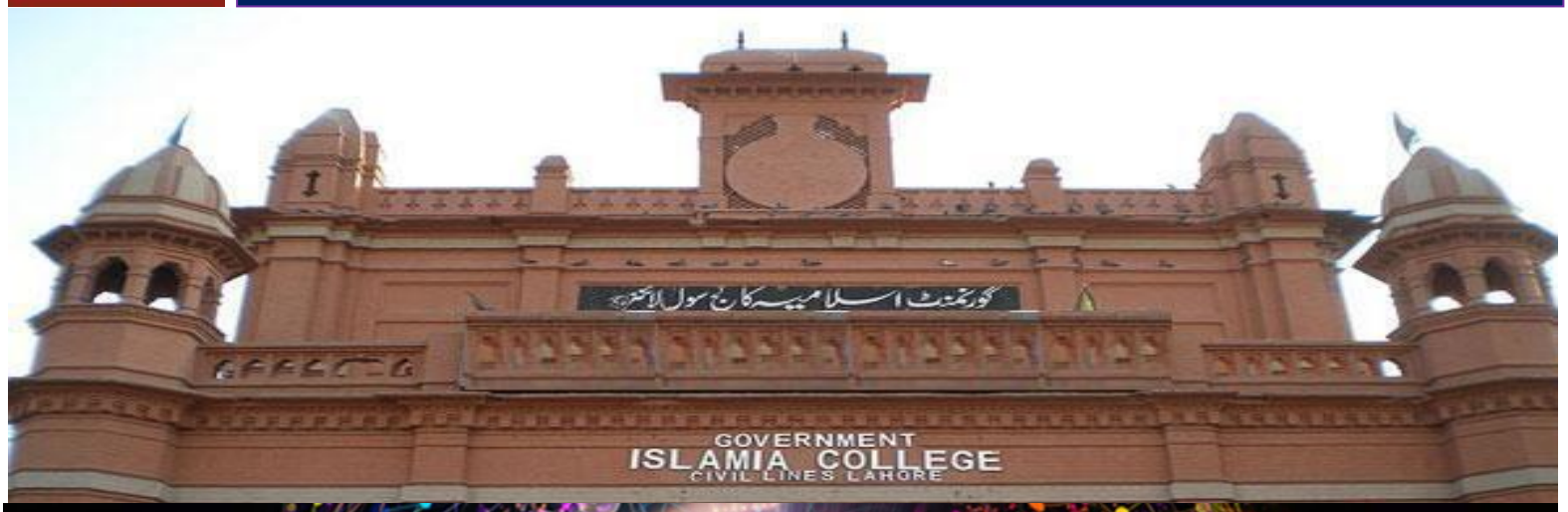

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Table of Contents

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Face Detectors Evaluation to Select the Fastest among DLIB, HAAR Cascade, and MTCNN

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ABSTRACT

Face detection is an important problem in computer vision research and applications are getting trending due to the advancement in the file of machine learning and computer vision. There are several algorithms and models for face recognition. However, face detection is the first step in all implementations. This research proposed a face detection method based on an enhanced Multi-Task Convolution Neural Network (MTCNN) and improves the network of MTCNN, creates a neural network model based on MTCNN using Python, and cascades to increase the accuracy of face location in difficult scenarios. In this research paper, we evaluated the performance of three famous face detector models on CPU-based machines. Experiments show that HAAR Cascade is the fastest on CPU-based machines but in the case of accuracy, MTCNN is better. MTCNN and DLIB based detectors are designed for GPU-based machines.

Keywords: Face recognition, DLIB face detector, HAAR Cascade Classifier, MTCNN (Multi-Task Learning)

Introduction:

In the multimedia digital world, image and video are becoming extremely important. In every image or video, the human face is one of the most significant elements. Detecting the human faces in an image and subsequently extracting the facial characteristics is a useful technique for a variety of applications, including computer interface, video conferencing, and so on.

Detecting human faces and extracting facial characteristics from an image is, in reality, and a difficult task that has been researched in computer vision for decades. The goal of improving face recognition rates is to extract valuable facial features. It has been a challenging task in machine learning for a long time, with applications ranging from image classification, face analysis, face identification, face tracking, and need the monitoring and detection of several faces at a distance. The integral image, classifier learning using AdaBoost, and the HaarCascade are

three fundamental principles in the Viola-Jones face detector that make it possible to create an effective face detector that can execute in real-time.

Face detection is used to identify whether there are any faces in the image or not. Following Viola-Jones' pioneering work, other detection processes have been created to recognize faces efficiently and correctly [1]. The initial stage in a computerized face recognition system is face detection. It generally decides whether or not a picture has a face in it. If it does, it can track one or more facial positions in the image. The feature extraction stage includes selecting a unique feature vector from the identified face. Verification and identity are required for classification. To allow access to the desired identity, verification involves matching one face to another. Identification, on the other hand, compares a face to numerous other faces and offers numerous options for determining the face's identity [2]. Feature extraction subset feature and emotion classifier are the three phases. The feature value of the input picture, a face, is derived using Sobel edge detection and a Haar Cascades technique for feature extraction of the mouth and eyes [3]. Because of its robustness, we chose Haar cascade for face detection in this research. For feature extraction, there are two main approaches: holistic feature and local feature. The characteristics are retrieved from the entire face in the holistic feature-based method, which might be influenced by occlusion and expression variations. Local feature-based techniques, on the other hand, solve problems by considering sections of the image. They are also invariant in terms of size and rotation [4]. Filtering methods are another option to improve the accuracy of facial recognition [5].

To produce a discriminative subspace, different postural features are converted using a transformation dictionary. Face matching is done on a patch-by-patch basis rather than on a holistic level. Experimentation is carried out using the Multi-PIE, and FERET databases. When compared to existing approaches of posing issues and single-task-based baselines, the suggested technique produces better results. MTL techniques are used to improve these tasks. Face Recognition with MTL suggest that the characteristics of different postures be transformed into a discriminative subspace and that the transformations be learned simultaneously for all postures with one challenge for each posture for the MTL-based face recognition algorithm [6]. To rotate a face image, [7] creates a deep network. This multi-task framework outperforms the single-task model without the reconstruction component. Similar work [8] has been done in this way to extract robust identification traits while simultaneously synthesizing facial pictures.

Related Work

Computer vision is a topic of research that aims to create strategies to aid computers in analyzing the information of digital pictures like video and images. It's also automated processing, which includes several major procedures for image processing, recognition, and decision-making [9]. Faces are detected in a sliding window manner using new features and classifiers. Viola and Jones' remarkable work [41], AdaBoost is used with Haar cascade features in which it is used to train a cascaded face detector, which then influences various other techniques [10]. The Viola and Jones method use Haar classifiers to identify facial characteristics. In computer vision, Haar features are used to classify the intensity of pixels in a region in a detectable manner. Haar features are image rectangle areas, and classifiers are made up of two or three rectangle features that are continually inspected for features in the window. Face recognition systems that are robust to pose variations, and facial expressions [11]. The fundamental goal of these techniques is to find distinguishing characteristics. In general, these techniques may be split into two types: type one is to extract local characteristics, local appearance-based approaches are applied, and the facial

picture is separated into smaller sections [46]. Type two is to extract the features centered on these places, key-points algorithms are utilized to identify the facial picture.

Techniques Based on Local Appearance It's a geometrical methodology that's also referred to as a feature methodology. In this scenario, the facial picture is represented as a series of low-dimensional characteristic vectors. To describe local features, this concentrates on essential portions of the face and employs the face's uniqueness to identify and apply several parameters, such as pixel orientations, histograms [12], geometric features, and correlation planes [47]. LBP and variants: LBP is a general-purpose texture extraction approach that may be applied to any object [51]. It excels at face recognition [47], facial expression identification, texture classification, and texture segmentation. Facial image retrieval is an interesting but difficult challenge for its practical usage in computational forensics. It's much worse when the system doesn't identify the target image and it's only in the user's mind. As a result, accurate retrieval results require the user's descriptions of the target image. As a result, factor analysis techniques such as PCA, Fisher's linear discriminant, ICA, nonnegative matrix factorization, and probabilistic PCA were applied to these datasets. Facial recognition and retrieval are significant computer vision and image processing issues. The system works by retrieving valuable features to be used in the retrieval process, similar to face recognition systems. According to studies, interactive image retrieval has the benefits of incorporating user input and enhancing retrieval performance through relevance feedback.

To extract data, [13] employed an unsupervised deep learning system called the LBP network. The topology of the LBPNet is identical to that of the convolutional neural network (CNN). LBPNet is similar to other unsupervised approaches, according to experimental findings acquired using available benchmarks (e.g., LFW and FERET). Reference [55] developed a system for resolving face recognition problems including a wide range of characteristics such as emotion, lighting, and various positions. It is based on two different techniques: K-NN and Local Binary Pattern. The local binary pattern used face recognition algorithms to its invariance to target picture rotation. For feature extraction, reference [14] presented a variation of the local binary pattern methodology which is called "multiscale local binary pattern (MLBP)." The local ternary pattern methodology [15] is another local binary pattern variant that is less noise-sensitive than the original LBP methodology. The HOG technique can define the face shape by looking at the distribution of edge direction or the light intensity gradient [2]. This methodology works by dividing the entire face picture into cells, creating a histogram of pixel edge direction, and then combining the histograms to extract the face picture's feature. Reference [16] suggested a robust face recognition system based on a mixture of several histograms of oriented gradients (HOG). The approach is known as "multi-HOG."

In addition, a face detection system has been built to determine the item that looks like a face. Faces in the Wild and dataset of a wider face with a great degree of variety in circumstances such as size, position, occlusion, expression, cosmetics, backdrop, and light were used in this study. Reference [17] created the LWF image database to research the challenge of face recognition, which contains variations in posture, facial expression, lighting, age, gender, color saturation, image quality, clothing, focus, and other parameters. 13,233 facial images were acquired from the website, representing 5749 users, with two or more different images 1680 and each image having a resolution of 250 by 250 pixels. For the classification model, the dataset was divided into ten non-repeating subsets of image pairs. There are 300 positive pairs and 300 negative pairs in each subset. When the database is only used for checking, all of the pairs are used to

calculate accuracy. The database was created to research a special task that a pair of people had to complete. A pair of face images is given, and a classifier may identify the pair as "same" or "different" depending on whether or not the images depict the same person. A database was created to research a special task that a pair of people had to complete. Two procedures have been created to make use of the training data: Image-restricted and unrestricted training are also available. The identities of pictures are removed in image-restricted training. (1) Funneled images [18], (2) LFW-A employed an unknown process for alignment, and (3) deep funneled pictures [19] are the three types of aligned photographs presented. The WIDER Face [20] data set contains 32,203 photos, with 50% samples being utilized for training and 10% being utilized for validation. The poses, light, occlusion, and size of the faces in this data set vary substantially. Face detectors that have been trained on this data set have a greater performance [21].

Deep Face was trained on a large dataset of faces acquired from a sample that was significantly different from the people used to create the evaluation targets, and it outperformed existing methods with very slight adaptations [22]. The suggested method is different from the bulk of previous submissions in that it implements the deep learning (DL) model. With several significant advancements in different domains such as vision, voice, and language modeling, DL is particularly well suited for working with wide training sets [23]. The Convolutional neural network models combine the feature extractor and classifier from beginning to end. The techniques produce are useful in face representations. Many methods to improving face verification performance in an environment have been proposed, and some of them have shown positive results. Face identification makes extensive use of metric learning techniques, which are often combined with task-specific goals. MTL improves the performance at the same time. Face detection [24], Face alignment [25], pedestrian detection [26], attribute estimation [27], and other applications have all proven effective. Despite MTL's effectiveness in a variety of visual difficulties, there hasn't been much research done on it for face recognition.

For many facial analysis tasks, MTL algorithms are applied. Reference [28] was the first to examine the MTL framework for machine learning in-depth. It has since been utilized to solve a variety of computer vision challenges. Reference [29] offered one of the first MTL-based facial analysis studies. The method was used to solve face recognition, feature identification, and head-pose estimation. It combined a tree model with a pool of common components, each of which symbolizes a landmark place. JointCascad is another technique [28]. Combining the training with the landmarks localization challenge enhanced the face identification algorithm. Both of these systems relied on handmade components, making it difficult to apply the Multi-Task Learning paradigm to a wide range of activities. Because the feature representations required to accomplish each job were different, multi-task learning was limited to a few sets of tasks before the introduction of deep-learning algorithms. Face detection, for example, is often performed with HOG, whereas face recognition is often performed with LBPs. Likewise, distinct handmade characteristics were developed for age, gender, landmark localization, and attribute categorization. Handwritten characteristics were replaced by deep convolutional neural network features for facial analysis tasks as deep learning progressed. This allowed a single deep convolutional neural network model to be trained for a variety of tasks, including face detection, landmark localization, facial attribute prediction, and face recognition. When designing computers to execute various jobs, it's common to create separate algorithms for each and by exchanging deep features, one may create a neural network that can concurrently fulfill all of the requirements.

MTL is interpreted as a regularization strategy for a DCNN by [30]. Because the learned parameters of a network agree with all of the tasks at hand, the MTL methodology prevents overfitting and converges to a robust solution. Machine learning [31], and computer vision [22] have both done extensive research on MTL. To study common features and task-specific models, it is appropriate to combine MTL and CNN. For combined face identification, posture estimation, and landmark localization, [25] offers a deep CNN. Several techniques for training face-related tasks have recently combined the MTL framework with deep CNNs. Reference [32] advocated employing a CNN to simultaneously estimate age and gender. Hyper Face [33] trained an MTL network for face identification, landmark localization, posture, and gender estimation by combining the intermediate layers of CNN for better feature extraction. Reference [34] proposed an MTL-restricted Boltzmann machine for learning facial features, whereas reference [25] improved landmark localization by simultaneously training it with head-pose estimation and face attribute inference. These methods can perform MTL on a small number of tasks, but they are unable to train a large number of related tasks. Individual face analysis tasks have been the subject of much investigation. DP2MFD [33], Faceness [35], Hyperface [33], Faster-RCNN [36], and other deep CNN-based face detection algorithms have considerably outperformed classic algorithms like TSM [29] and NDPFace [37]. Due to a shortage of training data, only a few approaches have exploited deep CNNs for face alignment tasks [25-38]. Recent landmark localization algorithms have mostly focused on near-frontal faces [39], which have all of the key points visible. Recent techniques such as PIFA, 3DDFA, Hyperface, and CCL have been used to investigate face alignment.

Methodology

Face Detection

In the fields of image processing and pattern recognition, human face detection has proved to be a challenging problem. This step determines whether or not the given image contains any human faces. Variations in lighting and facial expression may make face identification difficult. A face recognition system's capacity to deal with images and videos, real-time, robust lighting situations and function with faces from various viewpoints are all aspects that make it successful. Furthermore, due to the lack of limitations on the quantity, position, size, and alignment of faces in an image or video scene, facial feature extraction is a time-consuming procedure. The proper method is to gather a large number of face and non-face samples, then use machine learning methods to train a face model for categorization. In this procedure, there are two major concerns: which characteristics to extract and which learning algorithm to use. Finally, the face recognition process compares the obtained attributes from the human face to all template face databases to determine human face identification. The three main approaches required to construct a decent face recognition system are face detection, feature extraction, and face recognition [40]. To facilitate the building of a more powerful facial recognition system easier, pre-processing methods are used. Only a few of the methods used to recognize and identify face images include the Viola-Jones detector [41], histogram of directed [42], and PCA [43].

Each face has its structure, size, and shape, allowing it to be identified. Some methods for identifying the face based on size and distance include extracting the contour of the lips, eyes, or nose [44]. HOG [45], Eigenface [46], independent component analysis, linear discriminant analysis **[**43], scale-invariant feature transform [47], Gabor filter, local phase quantization [48], Haar wavelets, Fourier transforms [49], and local binary pattern [44] are some of the techniques

used to extract face features. In the feature extraction stage, features are extracted from the environment and use to identify objects recorded in a database. Face recognition is used for identification as well as verification. A test face is compared against a group of faces to identify the most likely match throughout the identification process. During the identification stage, a test face is compared to a known face in the database to make the acceptance or rejection decision [45]. The success of correlation filters [50], convolutional neural networks [51], and k-nearest neighbor [52] has been demonstrated.

Figure 1 shows the design of face detection and face feature extraction system. The modules, face detection, and feature extraction use in this paper.

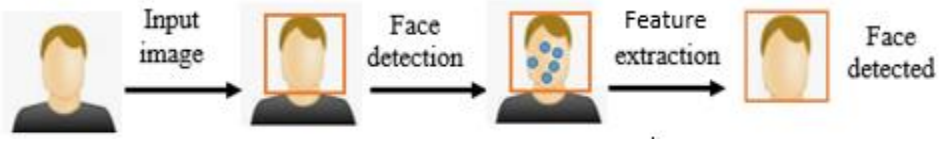

Fig 1 Face Detection and Feature Extraction model

In figure 1 Face detection is used in all facial recognition systems, however not all face detection methods are used for facial recognition. using cameras a human's facial movements convert into a digital database or face detection.

The initial step is to choose the digital image that will be used to apply the algorithms. The chosen image is referred to as the input image, as illustrated in Fig1. Face detection is the second phase, which involves determining whether or not there are any faces in a given image and, if so, returning the image position and content of each face. After the face detection, the face extraction procedure is carried out in order to offer relevant information for differentiating between various people's faces. Finally, a result is displayed, indicating that an image has been identified.

Face Detection Algorithms

a) Knowledge-based algorithms:

Describe in code the features that make up a real face, as well as the relationships between them, and make it simple to put up basic rules to differentiate between different face types. Face features are detected first in an image using programmed rules. Furthermore, covering all possible situations is challenging.

b) Feature invariant algorithms:

It includes a group of features that are similar to all faces and do not vary in response to changes in the environment, such as posture and light. Edge, intensity, size, texture, and color are all common features. These algorithms have a difficult task in identifying features in image corruption scenarios such as noise, lighting, and occlusion, as well as in complicated backgrounds.

c) Matching algorithms:

Different face formats are described by these algorithms. Face locations are usually specified based on edges, and correlation is used to identify them. They must be deformable to detect and adjust to the contours of the face. The primary disadvantage of knowledge-based algorithms is that they must cover all potential postures.

d) Appearance-based algorithms:

Create face templates using statistical and machine learning approaches such as classifiers, which include neural networks, PCA, and SVM, among others. Positive face samples, as varied as appropriate, and negative examples, with representative images that do not contain faces, are often used in the training of these algorithms.

e) Viola-Jones classical algorithm:

Viola-Jones algorithm has a higher detection speed in real-time face detection. The main characteristics of this algorithm are given below:

- By using the integral map to ensure the speed at which the feature is extracted value of the face image is extracted and, secondly, by using the Ada-Boost strong classifier, the correct rate of face detection is achieved.
- Modification of the standard Ada-Boost classifier. In the modern Ada-Boost classifier, several small decision trees construct the weak classifier and then cascade into a strong classifier. The Viola-Jones algorithms classifier for Ada-Boost cascade processing. A strong classifier is each new classifier constructed from this, which ensures a high rate of detection. Although face detection is the first step in any computerized system which solves face detection, facial expression, face tracking problems.

There are different ways of detecting faces and using these strategies, it is possible to identify faces with better accuracy. These methods, such as OpenCV, Neural Networks, Matlab, Python, and others, have the nearly same procedure for Face Detection. Face detection is the process of detecting numerous faces in an image. Using OpenCV to recognize faces, and there are a few steps to how to face detection works, which are as follows:

- The image is first imported by specifying the image's location. The image is next converted from RGB to Grayscale since faces are easier to identify in grayscale.
- The Haar-Like features method, introduced by Viola and Jones for face identification, is the next step. The position of human faces in a frame or picture is determined using this method.

Due to the integral image method, the HaarCascade features are highly efficient to calculate and give a better result for developing frontal face detectors. Researchers enhanced the simple characteristics with more variants in the ways rectangular features are combined in several follow-up studies. OpenCV is used to implement the face detection method. However, the model should obtain before the test phase of human face detection at the stage. Haar-like characteristics are used in a cascade of classifiers. The cascade classifier that comes with OpenCV 3.3.0 will be applied, thus no further training is required.

Results and Discussion

The collecting of high-resolution face expressions required the verification of data and computer expertise. The camera records information in a way that is directly connected to the camera. Automatic data entry may be made available with the support of integration, which improves the efficiency of data collecting. To complete the image segmentation, a face image collection algorithm relies on OpenCV and a frontal face recognition algorithm, data transformation, analysis of the changed data, and image classification by analysis of the parameters were implemented. The entire system design is separated into the image area. To use OpenCV's

"HaarCascade frontal face" file for image pre-storage, a C++ environment is required. The target file's information is identified, evaluated, and transforming the image into digital information. The digital image data is converted into an easy-to-store and-retrieve coding format. Using the OpenCV function cvHaarDetectObjects, which identifies an image from the target area, the pointer is used to execute cascade classifiers with varied parameters to retrieve different region information.

Above mentioned all detectors are used for Python-based implementation. Several hundred images are obtained by different cameras that include Webcam, CCTV 4K, and Mobile cameras. The image size is between 300 KB to 3.4 MB. All face recognition demos available online are modeled on a webcam that runs very fast.

Fig 2 Face recognition model installed in a shop.

Figure 2 shows four random pictures of the shop where the face recognition module is installed. In the real world, webcams are not used due to the poor quality of images. Therefore CCTV or HD cameras are installed in an optimal location for better face reading. The same demo programs give very low accuracy and speed when used with HD and CCTV cameras.

The system has been tested and evaluated and the following is how the database's data was gathered. The camera captured images of a group of people from which it is used to detect the images. Three algorithms (DLIB facial detector, Haar-Cascade face detector, and MTCNN facial detector) attempted to recognize faces based on these images. The MTCNN technique works by using multi-scale transformation to produce many rectangular frames of various sizes in the face data, performing sliding detection on the face picture, and extracting and detecting the characteristics of the rectangular frames.

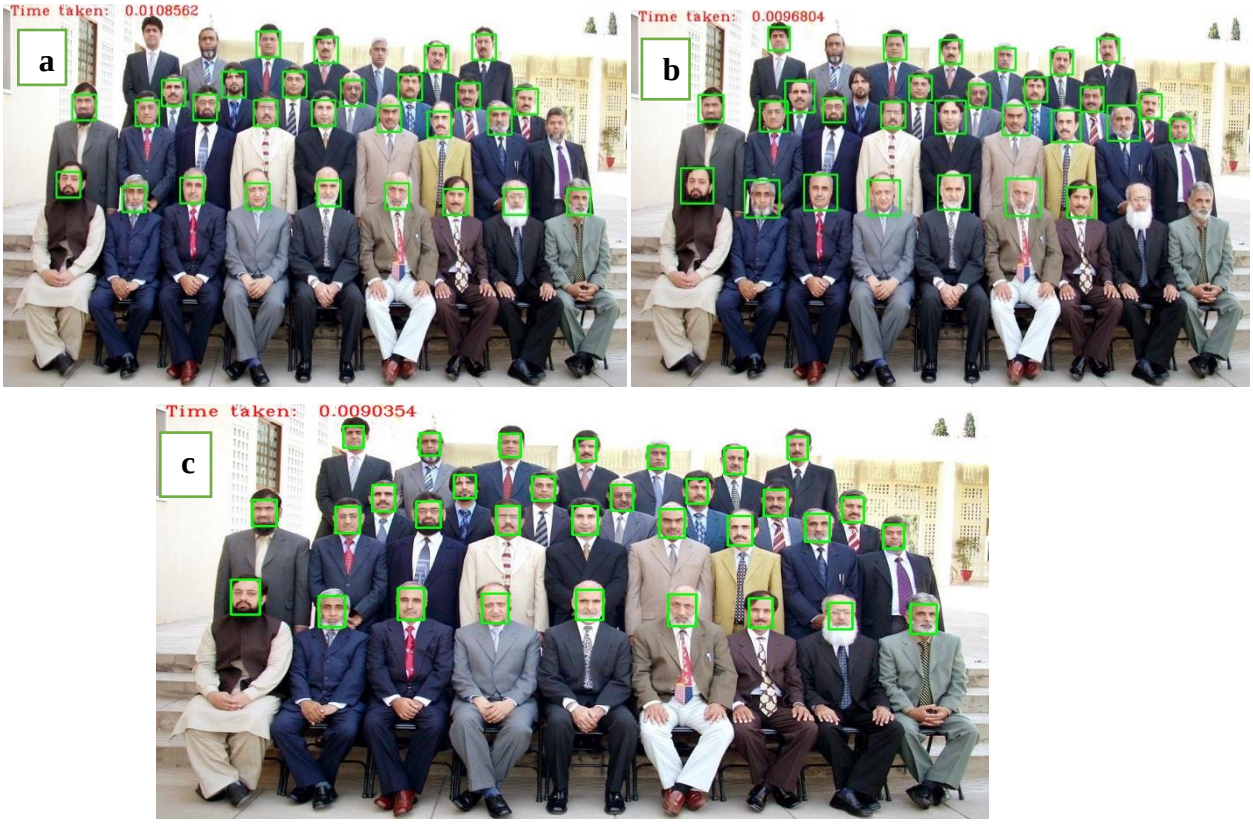

Fig 3 Qualitative detection accuracy of face detectors, a) shows Dlib, b) shows Haar Cascade, and c) shows MTCNN

Figure 3 shows the detection accuracy of face detectors used for experiments. All detectors are run based on their default configuration. It can be seen that MTCNN accuracy is better than the other two detectors on the default configuration. However, DLIB configuration if changed can get all faces to detect but with many false positives. The DLIB achieves good precision on default configuration with low recall.

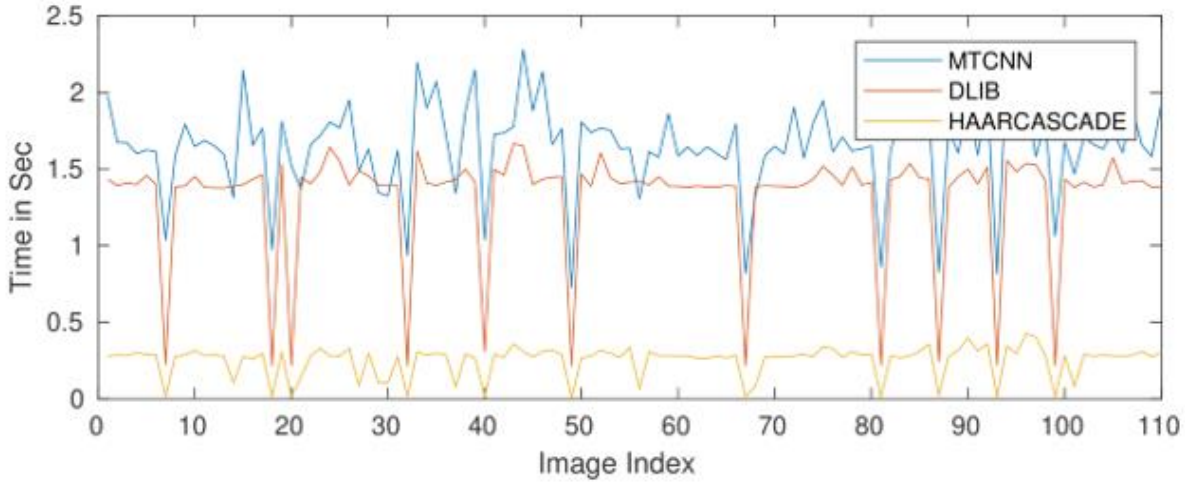

Fig 4 Detection time of face detectors.

Figure 4 shows the graph of different detectors. This graph is generated by using the images with different resolutions and sizes which is obtained from different cameras. The experiment is conducted to detect the faces on the default configuration.

The graph in figure 4 also shows that the HAAR cascade is the fastest on the default configuration. However, experiments also show that HAAR cascade precision is low compared to DLIB and MTCNN. The DLIB detector uses HOG based detector for CPU computation.

Conclusion

In this research, famous three face detectors are evaluated against the efficiency matrix, where time is the prime parameter. The detector includes HAAR cascade, DLIB, and MTCNN. All these detectors are available for all famous languages such as C, C#, Matlab, and Python. For experiments, we have used Python-based implementation. Experiments show that the HAAR cascade has better performance on the default configuration. However, the precision of the HAAR cascade is lower compared to DLIB but with better recall. The DLIB detector is widely used for face recognition applications as lower recall misses small faces on the default configuration.

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AUTOMATIC CV RANKING USING DOCUMENT VECTOR AND WORD EMBEDDING

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ABSTRACT

This research is based on the practical facts related to the human resource department of any organization for the recruitment of personnel. As it is a challenging and crucial aspect for any organization to select the right talent for the right place. This paper helps in expertise finding in the different fields of Computer Science. Employers receive a bunch of resumes upon job openings. And the candidates are also interested are in sifting the best among the applicants. Screening the best candidate among the pool of resumes is a laborious task. This paper proposes an informational retrieval-based resume ranking scheme for screening and ranking the candidate's resumes. The primary purpose of this research study is to exploit the class NLP techniques to perform the information retrieval task for resume ranking based on job description similarity. In this proposed methodology, we compared document vectors with word embedding. Experiments show that word embedding method is more effective than the document vector.

Keywords: Word Embedding, Informational Retrieval, TFIDF.

Introduction:

Information retrieval (IR) models are composed of an indexed and a scoring or ranking function. An IR system's main purpose is to retrieve relevant documents or web pages in response to customer requests. The scoring mechanism is employed during the retrieval to order the recovered documents according to their relevance to the user query. The standard technique is used to overcome train word or paragraph embeddings on a corpus or use pre-trained embeddings. WE stand for word embeddings, which are distributed representations of phrases derived from a neural network model. In recent years, these continuous representations have been employed in a variety of natural language processing applications. This approach's effectiveness for classification and other NLP tasks is demonstrated by the fact that semantically similar terms are grouped near to

each other in the representation space. Transferring the success of word embeddings to the ad-hoc Information Retrieval (IR) problem, on the other hand, is a widely researched topic right now.

Hiring the right talent is a big challenge for all companies. A business that requires full effort developing and facing high rates of attrition. Today's competition is at a high peak.it has become a challenging task for the job provider as well as a job seeker to get the one as the expert. For job providers, the challenging task is the extraction of required data. In our case, we have a set of CVs, but job descriptions are unknown, therefore we need to come up with a solution based on unsupervised learning. As a result, word embeddings appear to be a suitable place to start our research. In a high-dimensional space, word embedding computes semantically meaningful vector representations of words. Recent word embedding approaches outperform older methods of representing a word as a vector, such as the bag-of-words representation or latent semantic indexing. Advanced word embedding techniques and the use of multidimensional transformation matrices to flexibly capture different semantics of a single word, leading to better representations for part-of-speech tagging tasks, have recently been actively studied since such word embedding techniques have shown their advantages in numerous tasks in natural language processing and information retrieval.

In the case of job seekers the challenge to get to the place where their talent could be utilized. The traditional approach of applying to the job is to look for the job and then apply by sending a resume or curriculum vitae (CV) to the place. As manually it is difficult. Large enterprise and head-searchers receive every day thousands of curriculum vitae CVs/resumes from applicants. Consequently, reviewing a large number of CVs/resumes manually is time-wasting. And also, with the growing need for research and development, many of the organizations are hunting for good researchable talent. Many Ph.D. scholars who complete their degrees mention their specialization by giving a short detail of a particular topic on their CVs. This can attract hiring companies. Efficient Automatic CV shortlisting will not only make the lives of employers easy but also make the recruitment process fast and efficient[1]. Reference [2], introduce high-level ontologies with domain-specific knowledge is introduced to meet the requirements of the job market.

Furthermore, in this paper, a process is introduced which is used to update the existing ontology with the concept of formal analysis. For job recruitment matching of the semantic base, ontology is performed. Constructing quality ontology is crucial. Resume Resource Description Framework (RDF) [3], and Description of Career (DOAC) are frameworks based on ontologies. These studies are designed with the help of ontologies. Resume RDF is used for the description of the semantics of resumes and includes information such as skill, the experience of work, qualification, etc. Description of a career is another study that is the same as the Resume RDF. DOAC is the vocabulary used to describe the resumes if we talk about the performance of these two studies. The rate of generation of Resume RDF of queries as result is higher than DOAC. The main interest of this study was to find resumes that are appropriate matches for a required job description. Carrying out several experiments on CV/resume dataset as dataset consists of millions of resumes. In this research, candidates are short-listed by using different Natural Language Processing (NLP) techniques to find expertise in different fields of computer science. While word embeddings have been proven to improve in different NLP tasks, they have not yet been designed to improve text retrieval in software engineering to our knowledge.

Literature Review:

Automatic CV Shortlisting for Expert Finding is the highly recommended tool for the recruitment process as it can speed up the process of screening as compared to manual screening this research describes a ranking system that shortlists the candidates for a particular job. The experiments have been carried out on 169 CVs/resumes of the dataset against 25 to 30 job categories. The calculation of text similarity has been an essential approach of data analysis that may be used in a variety of NLP applications such as information retrieval and sentiment analysis. For retrieving our required results two NLP techniques like Term Frequency–Inverse Document Frequency (TFIDF), and word embedding have been used. The Jaccard coefficient, cosine similarity of TFIDF vectors, and cosine similarity of log TFIDF vectors were used in comparative research to assess the semantic similarity of academic articles and patents [4]. All of these approaches are corpus-based, and a case study was conducted for further research [5], which looked into the many uses of semantic similarity in the field of Social Network Analysis. Additionally, for ranking of CVs/resumes Google word embeddings are used as these are already trained. Much other research has been presented for expert findings. Each of the techniques has a different procedure for hunting the right talent for a particular post. Techniques such as collaborative filtering to the recruitment of candidate's job matching [6]. X.YI.j Allan and W.B craft expressed a method that uses a model of relevance to handle the vocabulary which is divided between a description of jobs and CV/resumes.

A semantic similarity computation method [7] that compared and analyzed multiple words using a huge corpus. The Word2Vec model was used to compute semantic information from the corpus, and the Li similarity measure was used to compute similarity. Automata collaboration in the system "CASPER" in this system the profiles of users are achieved from a user [8]. Such as data revisit, data read time, and data retrieving. These are factors that are viewed as a measure of relevance among resumes. This system recommends the job into these steps: first, this system searches a set of users who are related to the job. Second the user-related liked jobs are recommended to a large number of candidates. In this system, a strategy that is used is known as cluster-based collaboration filtering. It allows the jobseeker to find a job through a query that contains the same fields such as candidate location, candidate salary, and skills. Reference [9], has worked on a recommended system which is using a hybrid approach. This system is a combination of methods, such as content-based filtering and collaborative filtering. This system attempts to control the rating of data sparseness y grasping a model which is integrated, includes the synthetic resumes as a dataset.

About [10], job recommender system, the user data is asked to input user's required data into a form that is a web-based interface. The data which is collected consists of demographic data, educational data, intermediate and university exams, and post-graduate degree, experience the job, skills in languages, and skills in IT, and users are also asked to upload their CVs/resumes. Furthermore, a statistical model is used for other aspects such as talent. This model requires to be trained before use. To train the recommender model the user's searched outcomes are used as training data. Therefore, training time will be long enough for each user. Reference [11], introduced a recruiting system "PROSPECT" to help in shortlisting candidates. A resume miner is used for extracting information from CVs/resumes. Then the algorithms such as BM25, Okapi, and KL were used to solve the same problem. This system is presented by [12]. If we talk about dictionaries, we know that every day new terms have appeared, so for that purpose, the dictionaries must be updated as these are going to be used in tagging the entries. The learning model which is

adopted used in this system used to gain two targets: at first, for enhancing the information extraction semantic data should be used, and second, new terms should be discovered. A system that has a hybrid recommender, which has two types of relationships one is content-based and the second is interaction-based [13]. In the first relation, the sequence of relations is as follows job-to-job, job-to-job seeker, and job seeker-to-job seeker are identified concerning their similarity. For calculating similarities two approaches are used, for example, the structured data such as for age and gender the value-weighted sum will be produced and other is unstructured such as the similarity between job and CVs/resumes and latent semantic analysis is also used in this hybrid recommender. In E-Gen, we evaluated and classified unstructured job descriptions to improve their relevance[1].

Reference [14], In contrast to the above-discussed works, said that for facilitating easy communication, they recommend using a common language. Because it would create potential automation in the phases of the recruiting process. Not only will this keyword from ruled vocabulary be used, which aid in combining the background knowledge to the domain of industry. Furthermore, these approaches are used to incorporate with ontology to determine that at which degree the match between position and applicant is performed. This is also very critical because it also occurs when the ontologies are reused. Reference [15], has discussed these issues and suggests that further manual work is required. Reference [16], proposed jointly working on Turkey's largest online recruitment website Kariyer.net. In this project, free-structured resumes are converted into label base Resume Parser (ORP) works on a large number of resumes written in Turkish and English. Semantic web and ontology are combined to form a web Ontology. A machine learning algorithm is employed to rate the candidates and conduct semantic matching techniques. The goal of this study is to assess job candidates in e-recruitment [17]. There is some detail of related works: Resume RDF, a resume ontology developed by [3], describes information from a resume by its classes and properties. A method that results in the semantic orientation of words in corpus corpora and their connection with other words [18]. An approach for retrieving information from resumes that uses the notion of sharing data to find new types of data [19]. Recent word embedding methods such as word2vec [20] and GloVe [21] have two notable advantages in terms of high-level semantics compared to traditional methods of representing a word as a vector, such as the bag-of-words representation [22] or latent semantic indexing: meaningful nearest neighbours and linear substructures [21].

In terms of the first, these approaches successfully capture semantically related words in a vector space as the n nearest neighbors of a certain word. When it comes to linear substructures, the vector created by removing two words in a vector space frequently gives semantics that contradicts the word. Since word embedding approaches have demonstrated their utility in a variety of natural language processing and information retrieval applications, sophisticated word embedding techniques have lately received a lot of attention. Word embeddings are vector representations of a word produced through the use of a large corpus to train a neural network. It has been frequently used to classify texts based on semantic similarity. One of the most popular types of word embeddings is Word2vec. The word2vec algorithm takes a text corpus as input and outputs word vectors, which can then be used to train any other word to get its vector value. Based on the distributional hypothesis, the Word2vec model employs a continuous skip-gram model [23]. Gensim [24], an open-source toolkit, includes several pre-trained word2vec models based on various datasets such as GloVe, google news, ConceptNet, Wikipedia, and Twitter [24]. To construct feature vectors for the dataset in this experiment, a pre-trained word embeddings model

called ConceptNet Number batch [25] was utilized as a word2vec model. There are several distributional semantic models (DSMs) that have been suggested. Each word in a DSM is represented as a d-dimensional vector of real values, with comparable vector representations for words that appear in similar contexts. Count-based models make up the majority of classic DSMs. Some new neural network models have recently been presented [20]. Deep neural networks are used in these techniques to learn from the context of the corpus and produce low-dimensional word vector representations, a process known as "word embedding." For different information retrieval tasks, word embedding models have been shown to perform much better than standard count-based models [26].

Many information retrieval tasks exist in software engineering, such as duplicate issue detection in open source projects and tag recommendation in Q&A websites [27]. The majority of them expand classic information retrieval techniques like cosine similarity and the TFIDF approach to obtain high performance on these tasks. Word embedding algorithms have recently been applied to numerous information retrieval problems in software engineering, with promising results [26]. Traditional information retrieval approaches such as the TFIDF method focus more on the relationship of various documents in the entire corpus, whereas word embedding techniques focus more on the relationship of words considering the context in which they appear.

Methodology

Our proposed methodology for resume ranking is based on two famous approaches in information retrieval. The classical and widely used approach is document vector in which document is represented by some predefined vocabulary. Figure 1 shows the document representation using the first approach. The vector is usually very sparse as the length of the vocabulary is kept very high. The document vector usually used a weighting schema known as TFIDF (Term frequency-inverse document frequency**)** which reduces the weight of very frequent words in corpus and gives high weights to the least frequent words. The main limitation of this approach is that it doesn't account for the context of the text. Two different documents with the same words are considered similar. To overcome the above-mentioned limitation, word2vec or word embedding-based approaches are used. In word embedding, the vector is obtained against every word in the predefined vocabulary and those vectors are concatenated to represent the document.

In our proposed scheme initially, the resume /CVs corpus is preprocessed and cleaned. The processed text is now ready to be fed in the TFIDF mechanism and word embedding. The term-frequency and inverse document frequency is used to create the feature vector R^n which allows giving more weight to the key terms. The job description object is also processed in the same manner as the resume corpus which is further used as a query in our information retrieval system. Eventually, the cosine similarity is computed to estimate the proximity of resumes with job description objects. The ranked resumes are finally sorted and filtered for a certain threshold. Our second method is based on Google word embedding which uses the state-of-the-art Word2vec. The study is aimed at empirically evaluating both NLP schemes to create a generic model for resume/CVs ranking. To assess the accuracy of our model we have intended to estimate the precision and recall using a human-annotated rank list as ground truth. Word2Vec creates a vector space with each unique word in the corpus, generally with several hundred dimensions, such that words with similar contexts in the corpus are close to one another in the space. This may be

achieved in two ways: starting with a single word and predicting its context, or starting with the context and predicting a word.

Cosine Similarity using TFIDF Vectors: A vectorized TFIDF model was used to transform the preprocessed documents into TFIDF vectors. The resulting vectors were a sparse matrix with TFIDF weights for each word in each document, with a size of [number of documents * number of features(unique words)]. These TFIDF weights from the matrix are now used as a feature for each document, and cosine similarity is used to compute document similarities.

Cosine Similarity using Word2Vec Vectors: The Google model was used to load the pre-trained word2vec model in this technique. The vector values or word embeddings of each word in all the preprocessed documents were computed using this word2vec model. The average of all the word vectors in a text was calculated, and the resulting vector was used as the document's feature word2vec vector. The cosine similarity inside the documents was computed using these word2vec vectors as feature vectors.

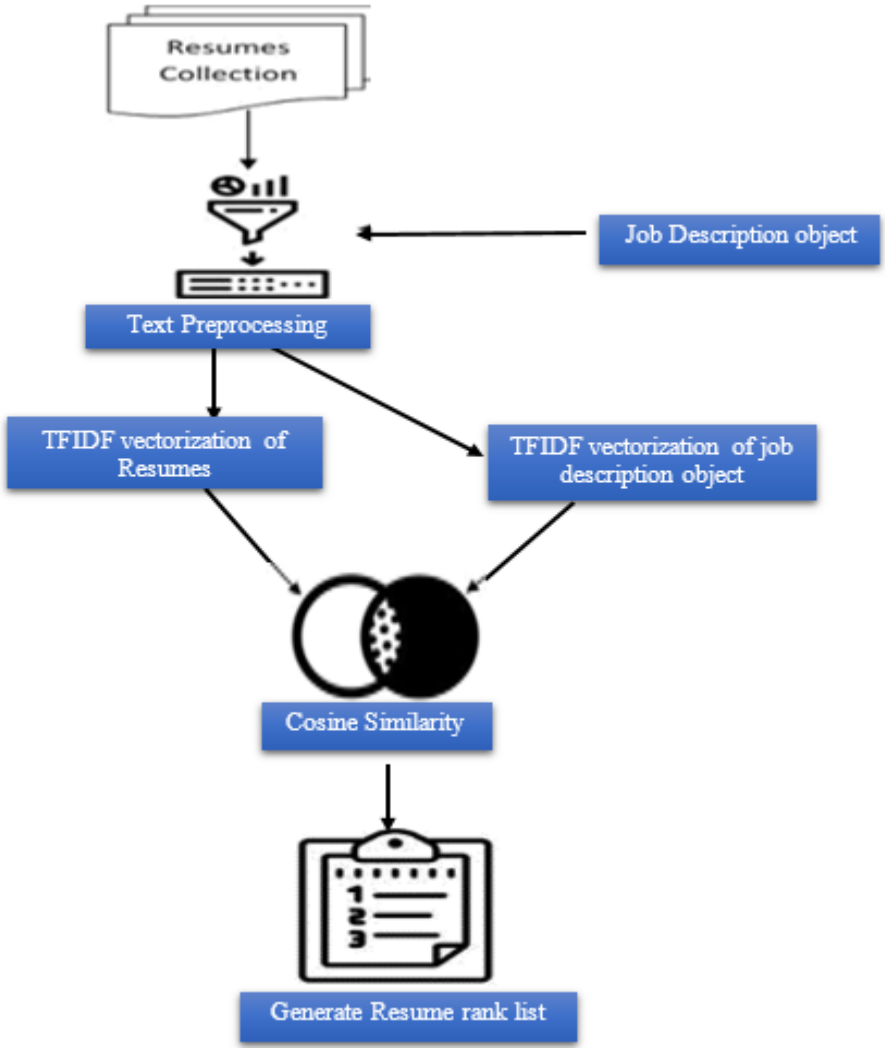

Fig. 1: Proposed methodology to compute document vector for the similarity.

In Fig. 1. The CVs corpus is preprocessed and cleaned. The processed text is now ready to be fed in the TFIDF mechanism and word embedding. The term-frequency and inverse document frequency is used to create the feature vector which allows giving more weight to the key terms. The job description object is processed in the same manner as the resume corpus. The cosine similarity is computed. The ranked resumes are finally sorted and filtered for a certain threshold.

Experiment:

Google word embeddings have been used to rank CVs; these word embeddings have already been trained by Google. Therefore, these embeddings were used to fit the model. We essentially used word embeddings to match our document. The average of each vector must be calculated separately to accomplish otherwise it will generate a three-dimensional vector. For this purpose, a word embedding function is created in which a specific word is selected, appended to embeddings, and the mean of that word is calculated. If no embedding for a given word exists, a random number is generated for that word. This random number will be trained later. After that, simply receiving the embeddings, stop words are removed and text cleaning will be used. Following that, the cosine similarity measure of the resulting vector is calculated. The mean word embedding of a query is also computed using Google word embedding concerning this cosine similarity.

A rank is generated after measuring the cosine similarity of a query with word embedding. Then according to this rank, the job descriptions are matched with the candidate's CV. A job description, for instance, is Hadoop. As a result, we've set some true positives that correspond to the job description for Hadoop. Hadoop itself, as well as some other related job titles such as Database Developer or Data Science Developer, will be tested for true positive. The total number of CVs in the dataset is 169. It displays the ranking of all CVs. Following that, ground truth is used to calculate the precision and recall of the rank list. In a nutshell, the entire operation comprises of the phases listed as: first and foremost, Google word embeddings were utilized.

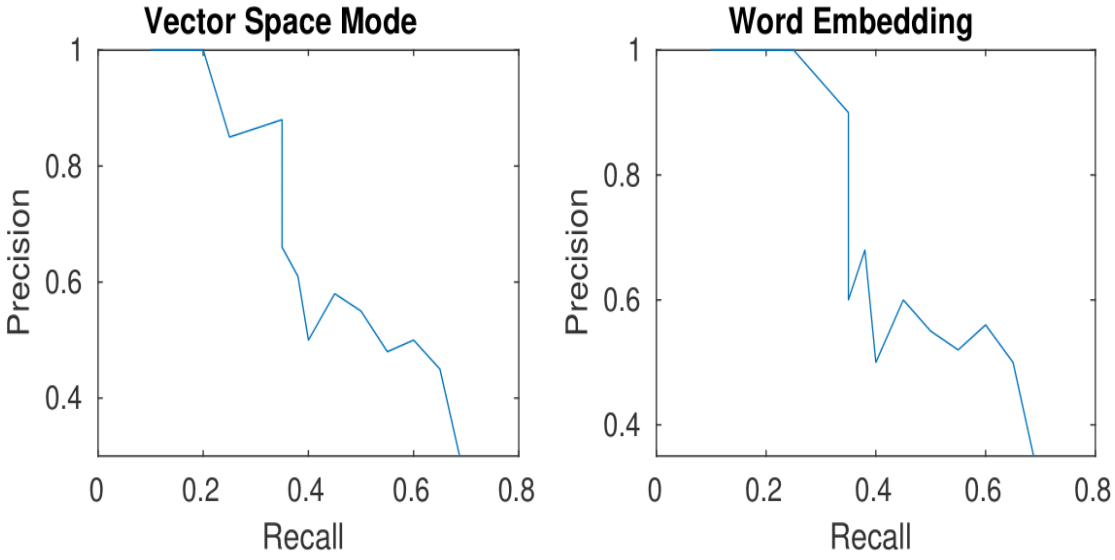

Fig 2: Precision and Recall of TFIDF and word embedding approaches

Figure 2 shows the precision and recall curves of document vector and word embedding. It can be seen that word embedding curve covers more area than the document vector. Which also that The word embedding-based approach is more effective than the document vector-based approach

The average word embedding of the entire document was then taken. Following that, cosine similarity was determined. As a result, a ranked list is created, and precision & recall are measured using this ranked list. There is a total of 169 CVs, with 25 to 30 job categories, such as Data Science, Hadoop, and Database Developer. Any of the job description categories can be queried to obtain a required ranked list of CVs.

Conclusion

This technology can speed up the recruiting process due to a combination of two aspects. First, rank the candidates according to how well they meet the job description. Furthermore, the usage of filters based on various information gathered from resumes helps screeners to look at fewer resumes to shortlist a set number of candidates. Second, showing snippets of resumes based on their match to job requirements and information extracted from resumes allows a screener to shortlist or reject candidates much more quickly than if they had to scan the entire resume. In this research, two famous approaches of information retrieval are evaluated for CV ranking. The word embedding-based approach is more effective than the document vector-based approach.

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DESIGN AND ANALYSIS OF PLC BASED INDUSTRIAL CONTROL SYSTEM

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ABSTRACT

The best quality production and the safety of human beings is the result of moderate and required conditions which are one of the most important industrial parameters. PLC is effective, fast responsive, and has a wide bandwidth. In this paper, we propose a technique of controlling different parameters of the industry through PLC based system by connecting the temperature, pressure, and level sensors with 2A4RTD. In any case of emergency, these sensors will detect the problem and making it easy to control and monitor the situation. 2A4RTD is a combo module that is used for taking analog and resistive inputs from the source, delivering them to the PLC 20-MAR board. PLC accepts the two analog inputs with the help of the 2A4RTD module, which has reduced the additional cost. After getting the information of the input signals, we can get the ranges of temperature, pressure, and oil levels. With the help of ranges, we can estimate the solutions to control their worst levels. Some components like the cooling fan, buzzer, and air conditioner will be connected with the relay or simply connected to the PLC board, to get the issues under control. Data will be collected and monitored through HMI.

Keywords: PLC, HMI, Temperature Sensor, Pressure Sensor

Introduction:

The moderate and required conditions are one of the most important industrial parameters for the best quality production and the safety of human beings. In the fields of scientific research and product manufacturing, controlling or monitoring pressure, liquid level, and temperature is very necessary especially in the case of atomic, metallurgy, fabrics, synthetic, fossil fuel, food, machinery, and building materials industries. To increase the efficiency of PLC logic code and reusing the code for multiple or different PLC categories, new technology is proposed. The ontology-based semantic model was developed. IEC 61131-3 cannot be used again., not just in terms of the file exchange format (syntactic), but also in the field of semantics. We offer an implementation of the auto-translation of XML schema and the PLC project into the ontology-

based knowledge model. PLC also provides security from cybercrime or cyber-attacks NNP environment using black chain technology [1-2].

For the effectiveness of heat control of different heat resources, a new method called dynamic matrix controller was introduced. It was dependent on the incorporation of nonlinearities. PLC was used as the main functioning block. DMC provides an equal balance between the performance control and PLC's memory load. It had used FOPDT approximations to perform operations on nonlinearities [3].

Developed a data collection and management system with an automatic lifting device, known as the data acquisition system. The micro-controller sends a motion control signal to the PLC, in accordance with the data to be processed. The PLC automatically develops the necessary speed and delay, operating curves, by the shift key. To get accurate speed control, motor control fuzzy PID approximation and the digital IIR filter method were used [4].

To improve the efficiency of thin-assessment, different NBI and IN properties, as well as a comparison of sparse recovery algorithms, have been tested to be able to exploit them, and the operational principle of IoT technology, the operational principle of RFID technology, and the operating mode of the PLC are to be considered as well. The creation of an automatic control system must be based on the status quo, development, general planning, and phased implementation by the school's real demands. The construction of a platform for the automatic settlement platform for the client's management subsystem, library monitoring subsystems, and access control subsystems must be addressed [5-6].

To investigate the responsiveness and voltage dip of different PLCs, several laboratory tests and mechanistic inspections were performed. It had shown that the rated voltage is affecting the responsiveness of the PLC. The voltage dip tolerance was dependent on the relationship of PS and DI modules in terms of AC-type PLCs. Whereas for DC-type, PLC's sensitivity didn't depend on the relationship of PS and DI modules [7].

To reduce the impact of linearity error of intelligent temperature transducer (ITT) operating characteristics and its offset and gain errors, experiments and simulations were done. Results had certified the exactness of functioning of the new auto-calibration procedure. It was elaborated that the resistor, power supply, and amplifier in the bridge were not necessary to implement. 4^{th}-degree polynomial presents the operating characteristic of the ITT measurement channel [8].

It was proposed that a small and low-loss PLC-based mode be used. The WFM technique was used to design a mode rotator with a curved trench construction. When compared to a typical straight-groove design, the suggested rotator mode, 45 percent of the overall volume (1.0 mm), and reduced loss (1/5) furthermore, the suggested mode rotator can be realized using low-mode interference. The suggested low-loss and small mode rotator device would be beneficial for the integration of PLC-based devices in multi-mode multiplexers [9-10].

A method is used to allow a designer to change the values, taken from SCT into a PLC application program, systematically corresponding to the international standard which states the main rules of PLC and Programming. The consequent program applies SCA which focuses on some problem that emerges in PLC-based control implementation, practically modeled as a DES. Using this method, one can reuse previous hardware and designed software for sequential controlling of subsystem [11].

Based on WFM optimization, a broadband PLC-based 2-mode MUX / DEMUX is suggested. Theoretical studies show that low-loss (0.3dB) and low-crosstalk (-13dB) losses can occur over a wide range of wavelengths ranging from 1400 to 1700 nm [12].

Using the system simulation process, the efficiency of the FFC design is improved under limited conditions. A lower 32bits valued is used in PLC to increase efficiency using a LU decomposition with pivoting, and a correction of operational sequences is developed. The main idea is to check whether the problem has been observed, which is compatible with the simulation of the behavior or not. The control signal is the data that is stored in the memory of a PLC that is used for this procedure [13-14].

Designed and integrated using a MUX/DEMUX mode, for LP01, LP11, A, LP11, B, and LP21 modes, all of which are operating in the C band, and with the help of silicon oxide, based on the PLC, with a uniform altitude of the LP11 mode controller. Our built-in PLC-based MUX/DEMUX mode, on a single chip, and for the first time, reached a multi-or the multiplexing of the four modes of operation. Developed two new "smart" electronic devices, which make the communication between the DSO and the communication bridge. Developed under CEI 0-21 standard measurement and safety requirements. In addition, most of the commercial, IP addresses, integrates the communication protocol and interface for communicating with both the DSOs (via PLC) and the inverters of DGs [15-16].

A new method of synchronizing time is based on IEC 61131-3 and model construction. The concept of extending the existing OPC level is also being developed. Suggested a standardized method for performing automated testing of complex structures (e.g., CTL, LTL) in PLC systems. This method is based on the Intermediate Model (IM), which seeks to transform PLC programs written in various standard languages (ST, SFC, and so on) into a range of modeling tools for verification tools [17].

Smart HEMS is designed to track, consumption, and performance. In the case of energy consumption, EMCUs are put in shops and lights to measure the energy consumption of household products, and the lamps using ZigBee, the data obtained is then transferred to the home section. The home server uses this software to determine the pattern of power usage in the house. PLC modems are put on each solar panel to check its status during electricity generation. The REG gathers status data for PLC solar panels as well as production data from RS-485 inverters and sends it to the home server. This PLC monitoring device can also keep track of each solar panel for maintenance purposes [18].

A new method for the transmission of the data was obtained during real-time monitoring of photovoltaic systems has been proposed. The voltage, current, and temperature of the PV panel are measured with the help of low-cost, intelligent monitoring, and the communication module and transmitted to the central control system is based on communication, materials, technology, power lines, the existing DC lines, thus avoiding the additional installation cost [19].

The quality of service (QoS) of wireless sensor networks (WSN) was primarily influenced due to the sensor node's failure. The percentage of sensor node failure was increasing because of the addition of the number of sensors. To tackle the problem, a method was presented, in which defective sensor node was marked up by calculating the RTD time of discrete round trip paths and comparing the calculated values with outset values [20].

To meet different industrial requirements, the temperature controlling and monitoring systems available on the market or in research laboratories vary in sensor and controlling channels configuration. Multiple AI-Meters were used to maintain communication between different channels. Without the check of bandwidth, number of bits for information frame, starting bit, number of terminating bits, odd or even parity, and digits that were transmitted between two communication sites because communication had been created in the operation of debugging [21].

Identified four key issues with the OPC interface: jitter, time delay, race status, and sluggish sample, and also proposed two solutions: A software-based solution is based on IEC 61131-3, as well as a new standard OPC solution [22].

Introducing the Web accessibility lab. For this, a PLC-based framework is developed to control the system. To monitor and manage the system, SCADA is installed in the test setup [23].

Two PLCs operate in the "master-slave" mode. In the first case, the master unit is being done, while the slave unit is in standby mode. The expansion module may be damaged, but with a lower failure rate than that of lead. During the operation, the final details of the master device and are, still to be sent to the slave [24].

The PLC regulates the operating parameters on the velocity required by the user, as well as the system's functioning in normal operating mode and shut down situations. Tests of an induction motor system driven by an inverter and controlled by a PLC demonstrate superior speed control precision when compared to a typical SI-control system. With the PLC control, efficiency may be enhanced to up to 95% of the synchronous speed. As a result, the PLC has earned a reputation as a flexible and effective instrument for use in industrial applications. They run in a synchronous, cyclic manner with a high degree of predictability. A response time of 1 m/s or even less, requires a very careful hardware selection. If a deterministic response time of less than 0.5 m/s is required, the PLC does not seem to be appropriate [25-26].

To perform Natural Language Processing (NLP) on sandhi language had used tokenization process. For the processing of tokenization different tools were deployed. In this process input language was converted into sentences, operations performed on IRT, sentences were broken into words, tokens in words and numbers were generated [27].

For face detection, a new method was introduced which works on the principle of MTCNN and enhanced the accuracy of the proposed network. This model was designed using python and cascades. Research had shown that HAAR is faster and MTCNN is better in the case of accuracy [28].

Proposed a method that described the resume ranking scheme for ranking the candidate’s CVs according to job requirements. For this, vector and word embedding mechanisms were deployed. Research had shown that word embedding was better than document vector [29].

The remaining part of this paper is structured as follows: describes the methodology and flowchart of the project. After that, it elaborates the experimental results of the project and gives the complete analysis that is available in the tabular format. Finally gives the conclusion and future work.

Methodology

Results and their description are illustrated below;

Block diagram

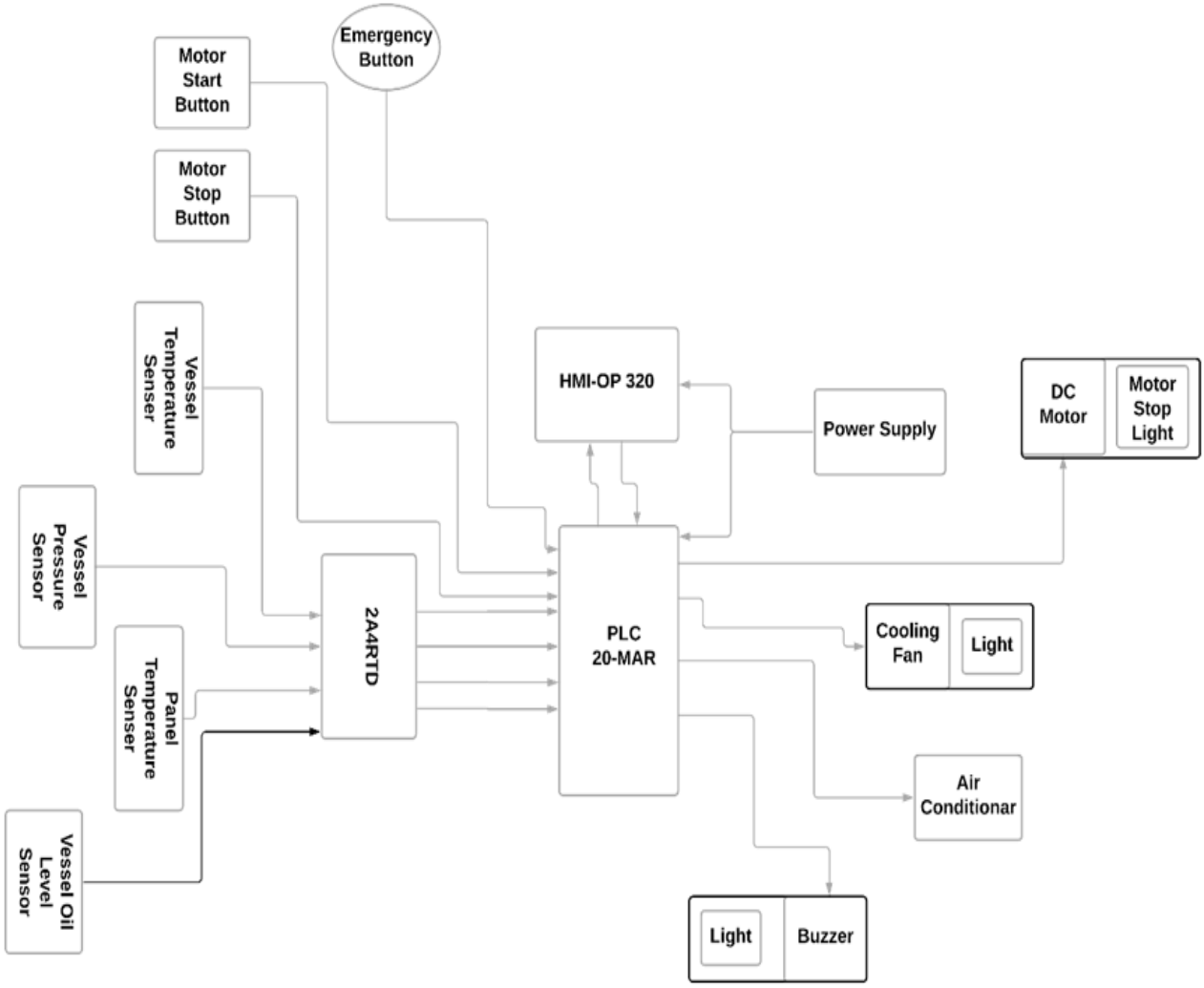

Fig. 1: Block Diagram of System

Description

The sensors after detecting the ambient conditions generate analog signals ranging between 0-10 Volts and transfer them towards the 2A4RTD combo card. After performing some operations on analog signals, the 2A4RTD module will transfer the signals toward the PLC 20 MAR. The PLC board performs the required actions according to the given conditions. Like, if the temperature is high or Oil level is low or it's crossing the limit and then the machinery temperature is high to a dangerous level according to the provided condition, PLC would start the fan, motor, air conditioner, and buzzer. At the same time, the data will be displayed on HMI.

Flow Chart

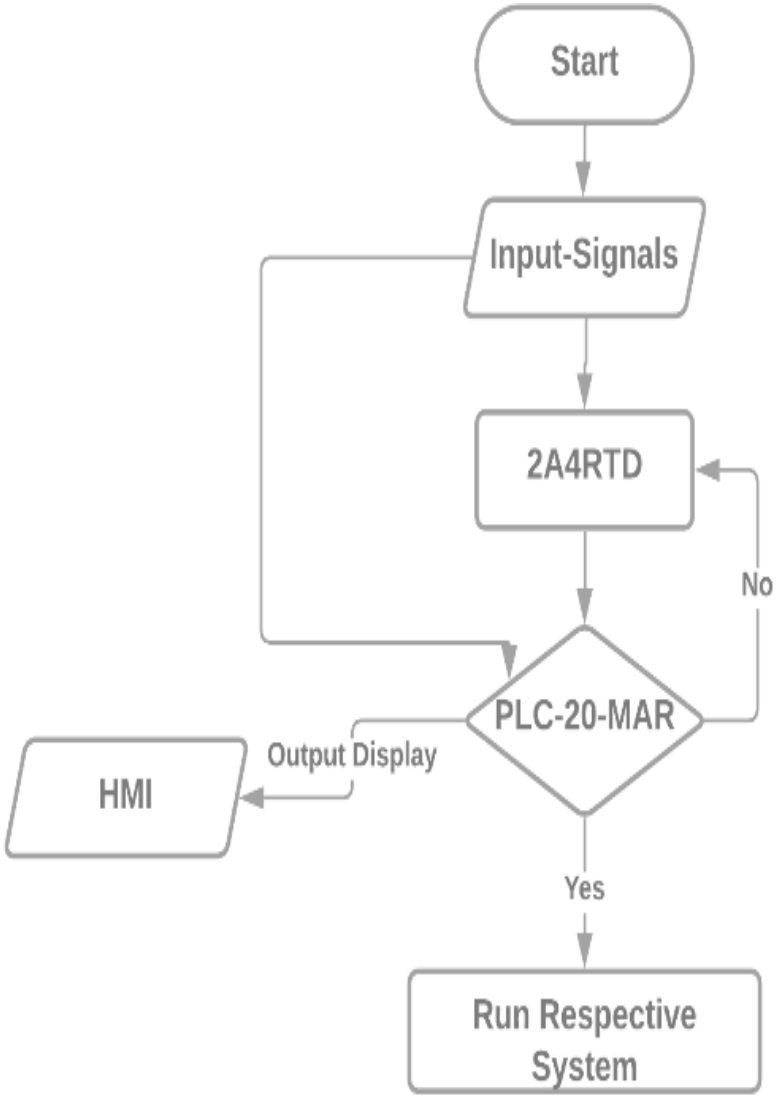

Figure. 2: Flow Chart of the System

Description

First, some of the input signals are sent to the 2A4RTD card and some of the signals are sent to PLC directly. Then these input signals are compared with thrash hold points at the comparator of PLC. And respective actions will be performed until the normal state is achieved. Its output, at the same time, will be displayed at HMI. The comparator with its logic will compare the input signals continuously.

Results and Discussion

Three sensors are used to control the vessel. A temperature sensor is used to monitor the internal temperature of the vessel. If the vessel temperature increases from the threshold condition, then the cooling fan turns ON to maintain the temperature level of oil. Whereas a pressure sensor is used to monitor the internal pressure of the vessel. If the oil pressure increases, then the buzzer started to alarm so that the control room can take safety actions. The oil level sensor will measure the level of oil in the vessel if the level is increasing or decreasing from the normal level then the motor will start or stop. There is another temperature sensor that is used to monitor the control room temperature. And if the temperature increases from a threshold value, then the air conditioner (AC) system of the room turns ON to balance the environment. Simultaneously, HMI is displaying the running state information.

Fig. 3: System Prototype

Vessel Temperature Monitoring

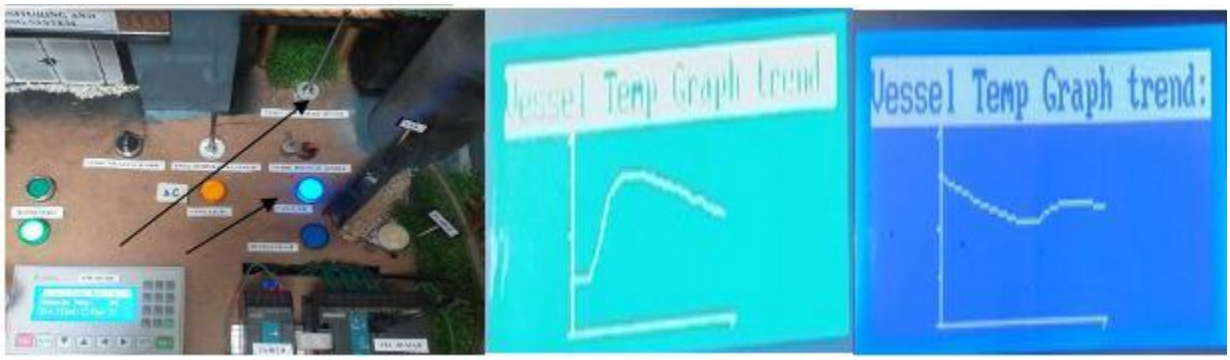

Fig. 4: Vessel Temperature Monitoring

Description

The vessel temperature sensor is measuring the temperature of the vessel and taking protective actions. Simultaneously, HMI is showing the temperature trend graph. On the y-axis, there are temperature (Celsius) values whereas on the x-axis there is time (seconds).

Pressure Monitoring

The vessel pressure sensor is measuring the pressure of the vessel and taking the defending actions. Simultaneously, HMI is displaying the running conditions like ambient pressure level and the moderate condition.

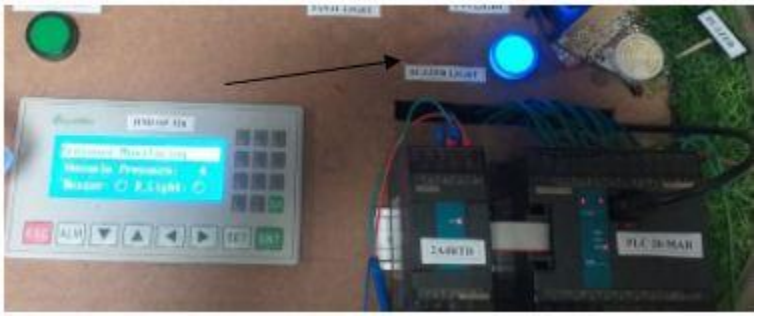

Fig. 5: Pressure Monitoring

Level Monitoring

The vessel level sensor is measuring the oil level of the vessel and taking the shielding actions. While simultaneously, HMI is displaying the running conditions like ambient oil level and the moderate level.

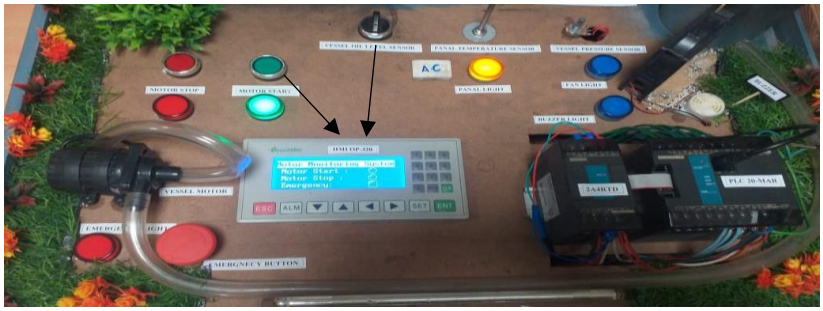

Fig. 6: Level Monitoring

Panel Temperature Monitoring

The panel temperature sensor is measuring the temperature of a control room and taking protective actions. Simultaneously, HMI is showing the temperature trend graph. On the y-axis, there are temperature (Celsius) values whereas on the x-axis there is time (seconds).

Fig. 7: Panel Temperature Monitoring

Conclusion

We have demonstrated a way to prevent, especially the industry from deadlier accidents that can lead any country toward economical and human lives crisis by the idea of system automation using PLC. We have used PLC FATEK-Fbs 20-MAR to control the industrial environment. To save cost, a 24ARTD combo module is deployed with PLC. It provides the compatibility of transferring the analog signal to PLC without the use of an A/D convertor. RTD PT-100 is used to sense the temperature. It is highly sensitive. It provides temperature ranges from 0° - 600° C. HMI (OP-320) has been connected to the control station for monitoring the running processes in the industry. It has some limitations like PLC, sensors, and other components that are of high cost. Sensors are highly fragile that they can break with a minimum hit. Data transfers rate is slow as compared to Nano controller. In the future, we are aimed to transmit data through Wi-Fi on the internet, so that we can monitor and control industrial systems through the online system. At the same time collected data will be monitored or controlled through HMI and sent to an open cloud source, any web page, or mobile application with the help of a Wi-Fi module. It will be helpful for industries as the information can be assessed easily through Wi-Fi no matter what is the location.

The results are concluded here in the following Table I.

Table I: Results

No. of Observations	Parameters	Normal Condition	Threshold Condition	Graphical Ranges	Graphical Time Span
1	Vessel Temperature	0° C ~ 34° C	35° C <=	33° C~ 89° C,	0s~90s
2	Vessel Pressure	0 ~ 3 Psi	4 Psi<=	-	-
3	Vessel Oil Level	150m ~ 200m	200m <	-	-
4	Panel Temperature	0° C ~ 39° C	40° C<=	24° C ~ 69° C	3s ~ 70s

Author's Contribution: H. S., and A. S., gave the idea; H. S., Designed the simulated work, and A. S., had collected or purchased the required data or components. H. S., A. S., and S. A. K., have integrated the system. Grammatical edits or Critical revision were done by H. S.

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STUDY THE NATURAL CONVECTION OF HEAT TRANSFER OF STRUCTURAL STEEL CYLINDER BY USING ANSYS TRANSIENT THERMAL

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ABSTRACT

Structural steel has become one of the most widespread building materials from last hundred year. It is broadly used in critical infrastructure such as buildings, cylinders, and marine pipelines, etc. In this paper, natural convection heat transfer is used for cooling steel cylinders by using ANSYS Transient Thermal. A cylinder is designed to have a radius of 10 mm and a depth of 40 mm. The initial temperature of the cylinder is 120°C and the ambient temperature is 22°C. When we apply a convection coefficient of $1x10^{-5}$ W/mm^2°C, the steel cylinder starts to cool down with the passage of time. The temperature decreases from 120°C to 22.357°C in the 10000s. These results show that the heat transfer (cooling rate) is rapid at the start of simulation but gradually decreases with the increase in time. When we apply the final convection coefficient of 2.2×10^{-5} W/mm^2°C, the temperature decreases from 120°C to 22.755°C in 3800s. These simulations show that the cooling rate has directly related to the Convection heat coefficient.

Keywords: Structural Steel, Convection heat transfer, Convection heat coefficient, ANSYS

Introduction:

Structural Steel has become one of the most widespread building materials from last hundred year. It is one of most usual constructional material which is extensively used in all aspect of modern-day construction. It has become one of the most widespread building materials from last hundred year. In soaring buildings, the dominance of structural steel is manifest and possesses substantial social and economic benefits [1, 2]. It is broadly used for critical infrastructures as ships, , marine pipelines, aircraft hangers, commercial and residential buildings, bridges, solid cylinders, warehouses, metro stations, , storage tanks, Harbor and offshores structure, etc. [3].

Fig. 1: Harbor facilities made by structural steel [4]

In several instances, rate of heat transfer is significant. Cooling of systems has great application in modern technology. They are extensively used in Automobiles and industrial equipment. The most efficient method of cooling includes: Cooling by water spray, mist cooling and forced convection by air jet cooling and applying high air pressure. In various parts, the convection heat transfer plays a significant role in transferring of heat. Natural convection has enough advantages as a tool of heat transfer. Natural convection uses the flow of fluid such as air on the surface of the material to transfer the heat from system to surrounding [5-8]. Convection heat transfer depend on three factors as temperature difference, area, convection coefficient [9].

The most significant parameter for the convection process is convection heat coefficient. It is truly dependent upon the wind velocity and other surface characteristics. The smooth surfaces have less convection coefficient as compared to rough surfaces under the constant velocity of wind. The faster velocities of wind correspond to the greater convection coefficient. This greater convection coefficient leads more heat transfer which cause a more rapid decrease in the temperatures of the bodies [10]. In this paper, we studied the behavior of cooling structural steel cylinder by using natural convection heat transfer. In many fields, a usual issue is natural convection of horizontal cylinder. Hundreds of researches have been initiated and completed to know the reasons of heat transfer in the air through horizontal cylinder [5].

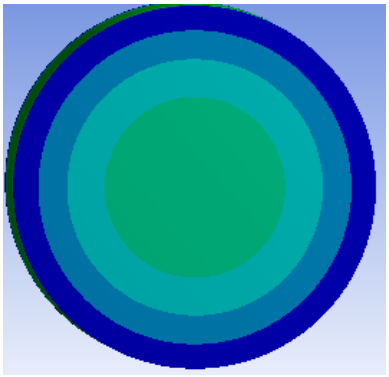


Fig. 2

Due to such importance of convection heat transfer, many researches and experiments are done in this field of convection heat transfer and Thermal Convection change in heat transfer in solid cylinder. In 1971, R.L Riley et al. studied about the air mixing, convection and Ultraviolet (UV) air disinfection in rooms [11]. In 1979, A.B Cohen analyzed the thickness of fin for improve of natural convection array of rectangular fins [12]. In 1983, A.B Cohen et al. analyzed the natural convection of thermally optimum arrays of fins and cards [13]. In 1991, H. Barthels et al. studied the experimental and theoretical investigation under the natural convection conditions for the safety behavior of small helium gas-cooled high temperatures reactors (HTRs) [14]. In 2000, K. Nakajima et al. examined about the moist convection of Jupiter's atmosphere by using 2-D fluid dynamical model with clarify cloud micro-physics of the water [15]. In 2002, Y. Bai et al. studied the systematic changes in apple rings in the course of convection air-drying along with controlled humidity and temperature [16]. In 2003, M. Iyengar et al. analyzed the coefficient of performance (COPT) in forced convection for plate fin heat sinks [17]. In 2008, N. Hatami et al. studied the natural convection heat transfer coefficient in a vertical flat-plate solar air heater [18]. In 2014, H.H. Al-Kayiem et al. predicted the convection heat transfer coefficient between flowing air and surfaces on the rectangular passage solar air heater [19]. In 2019, Y.G Lee et al. did tests on vertical tube of passive containment cooling system to study air-steam condensation under natural convection [20]. In 2019, A. Moradikazerouni et al. examined the computer's central processing unit (CPU) heat sink through stratified coerced convection by using structural stability method [21]. In 2020, M.H Alturaihi et al. studied heat transfer in square cavity filled with saturated porous media and fluid to look over thermal conductivity and void ratio [22]. Different researchers use ANSYS and Fuzzy simulation for different researches and get very useful results [23-38]

Simulation

ANSYS is an extremely impressive and innovatory software for multi-physics simulations. It is normally the most valuable and widespread software design which is utilized to illustrate the collaboration of comprehensive controls of pulsation, warm exchange alongside electromagnetic alteration, fluid, simple and physical skills for engineers. It is widely used in industry and engineering field for fluid dynamics, mechanical, electromagnetic, thermal and electrical simulations. In this work, convection heat transfer of solid cylinder in air is studied by using ANSYS Transient Thermal. ANSYS Workbench design modeler is used to create geometry of solid cylinder. Structural Steel is used to create geometry. The designed geometry consists of a solid cylinder having radius of 10 mm. The depth of solid cylinder is 40 mm.

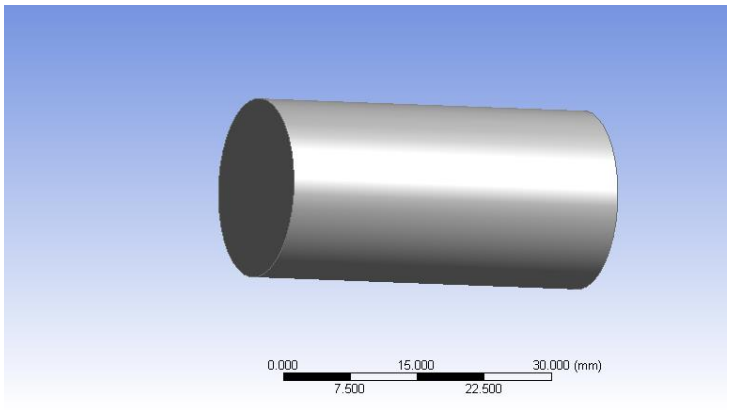


Fig. 2: Modeling of Solid Cylinder

To get more precise results or simulation, the geometry is exquisitely meshed with size element of 2 mm. The meshed setting contains moderate smoothing, admirable relevance center and fine span angle center. The meshed geometry has consisted of 6836 elements and 28510 nodes in total. The number of elements can be increased for more accurate results. But this finer meshing has drawback of processing time in simulation.

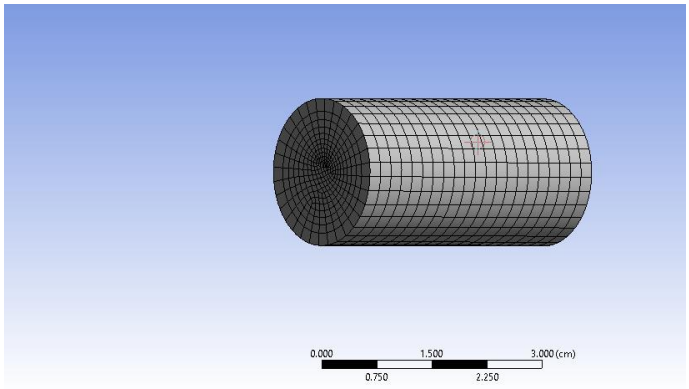
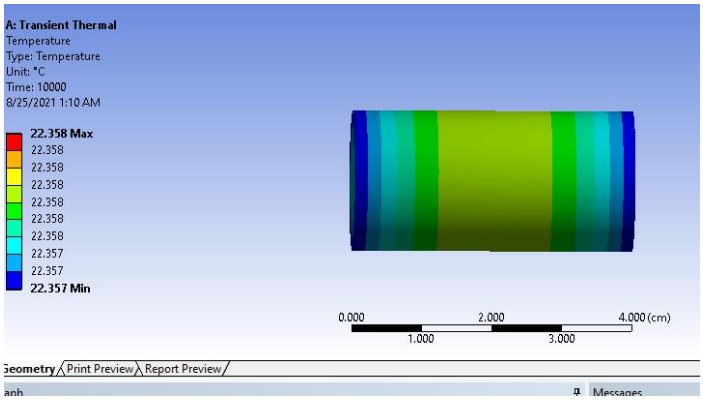


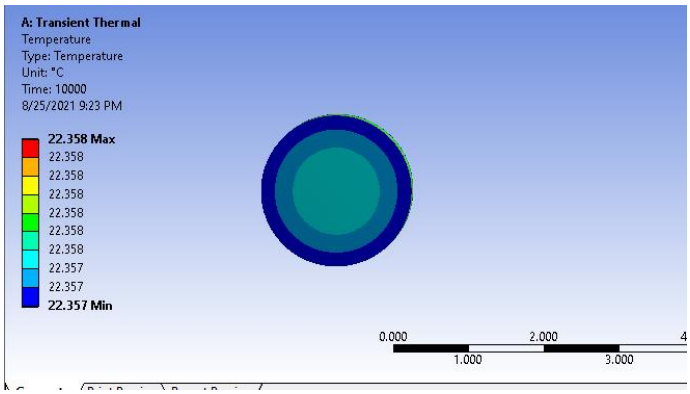
Fig. 3: Meshing of Solid Cylinder

Results and Discussion

ANSYS Transient Thermal is used to observe the convection heat transfer and cooling rate of the solid cylinder through air. The initial temperature given to the solid cylinder is 120°C. The Ambient temperature of the surrounding of the solid cylinder is 22°C. When we apply convection coefficient of 1×10^{-5} W/mm^2°C, the Structural steel cylinder starts to cool with passage of time. At 2000s, the cylindrical structural steel showed the minimum temperature of 46.728°C at the edges. At 4000s, the cylindrical structural steel showed the minimum temperature of 29.293°C at edges. At 6000s, the cylindrical structural steel showed the minimum temperature of 24.43°C at the edges. At 8000s, the cylindrical structural steel showed the minimum temperature of 22.894°C at the edges and at the time of 10000s, the cylinder showed the minimum temperature of 22.357°C at the edges. The results show that the temperature decreases earlier from center of cylinder as compared to the edges of the cylinder.



(a)



(b)

Fig. 4 (a,b) : Result of decrease in Temperature from the edge of the cylinder

Table: Time vs Temperature

Temperature with respect to time at convection heat coefficient of 1×10^{-5} W/mm^2 °C		
Serial No.	**Time (seconds)**	**Temperature (Celsius)**
1-	2000s	46.728°C
2-	4000s	29.293°C
3-	6000s	24.43°C
4-	8000s	22.894°C
5-	10000s	22.357°C

These results show that cooling rate is rapid at the start of simulation and decrease gradually with increase in time. The graph for the decrease in temperature with respect to time is shown in figure.

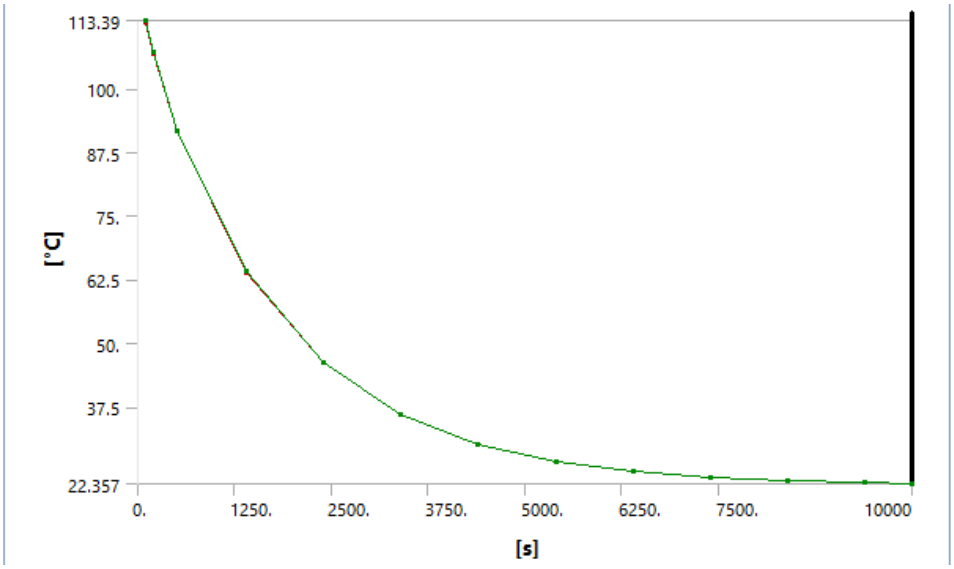
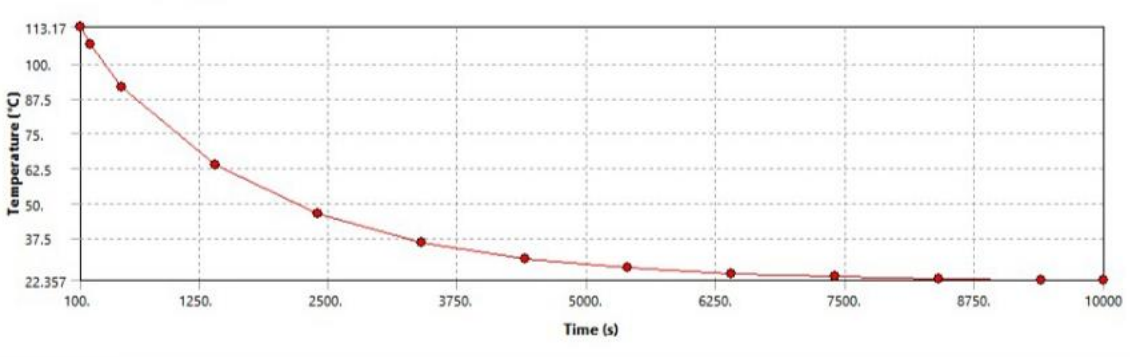
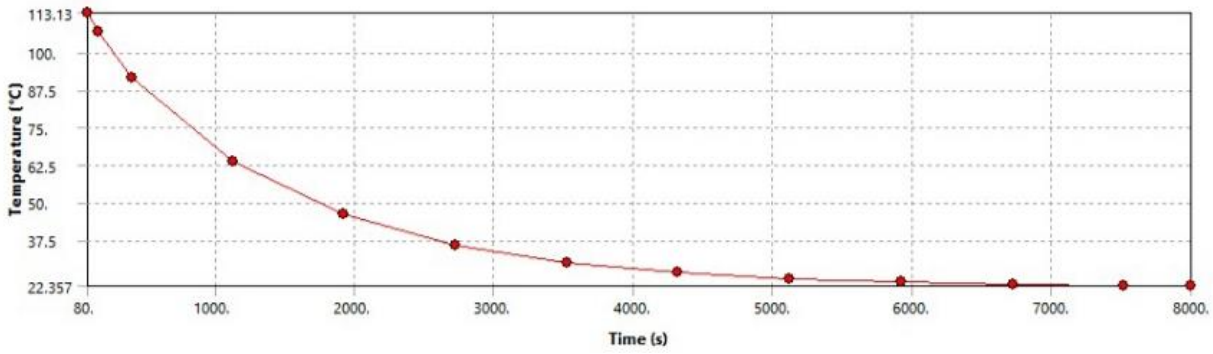


Fig. 5: Plot between temperature and time

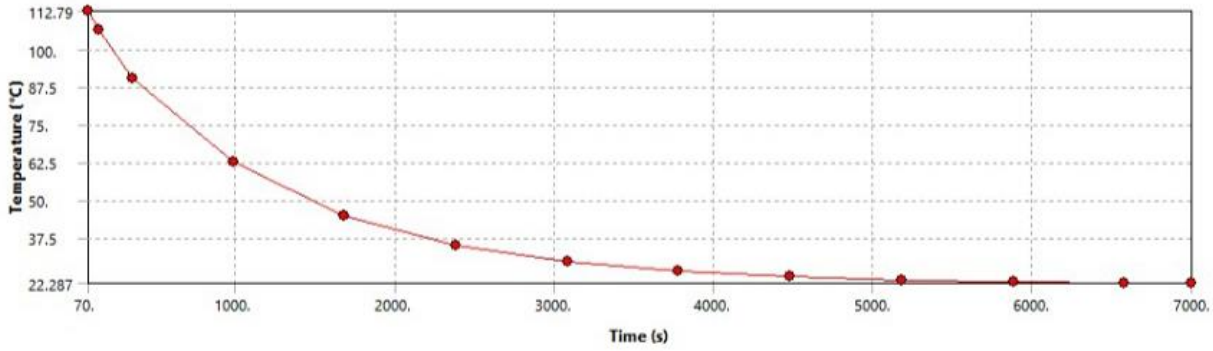
ANSYS Transient thermal is also used to observe the cooling rate with respect to convection heat coefficient. At convection heat coefficient of 1×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.357^{o}C in 10000s. When we increase the convection heat coefficient, it has favorable impacts on the cooling rate. At convection heat coefficient of 1.25×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.357^{o}C in 8000s. At convection heat coefficient of 1.5×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.287^{o}C in 7000s. At convection heat coefficient of 1.75×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.287^{o}C in 6000s. At convection heat coefficient of 2×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.56^{o}C in 4500s. At convection heat coefficient of 2.2×10^{-5} W/mm^{2o}C, the steel cylinder cooled down to temperature 22.755^{o}C in 3800s. These simulations show that heat transfer (cooling rate) of steel cylinder has directly related to the convection heat coefficient. The plotted graph showed that with the increased value of convection heat coefficient make the heat transfer (cooling rate) faster. These results from ANSYS simulation shows the same behavior with the previous researches as with the results of M. Saidi et al. [5]. The different graphs between temperature and time related to different convection heat coefficient are given below:



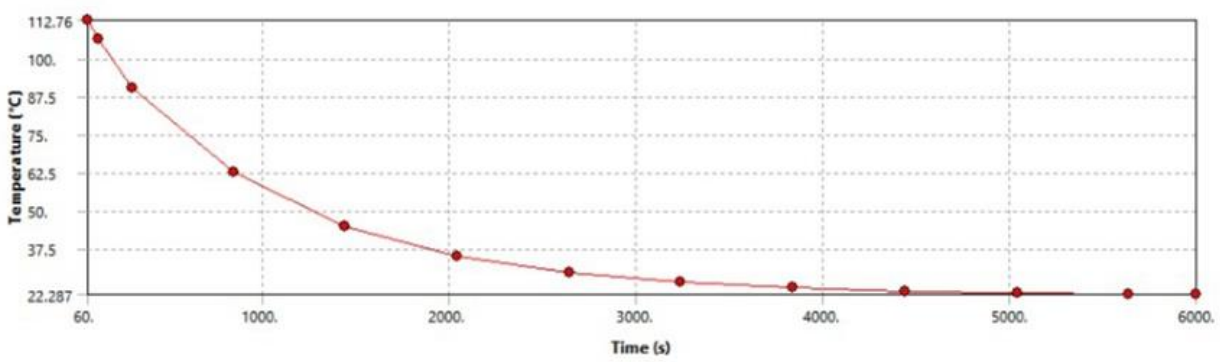
Graph. 1 (a): At convection coefficient of 1×10^{-5} W/mm^2 ^{o}C



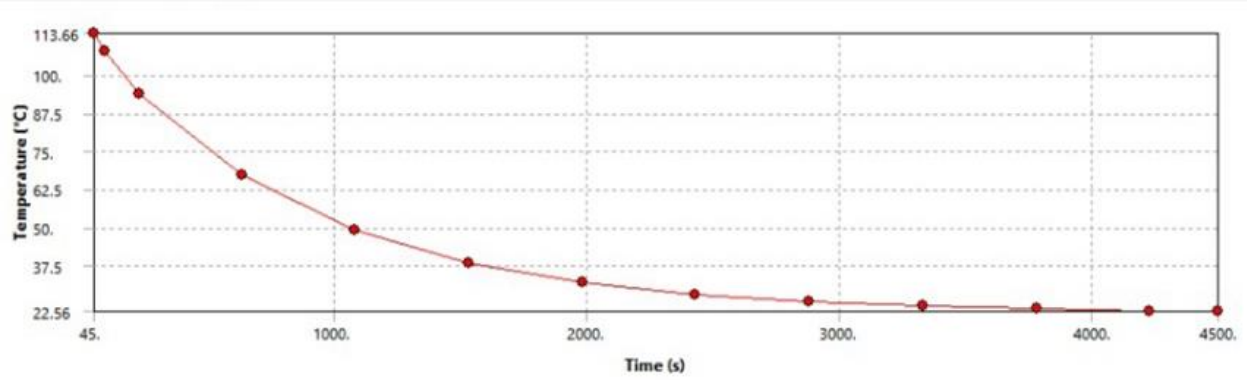
Graph. 1 (b): At convection coefficient of 1.25×10^{-5} W/mm^2 ^{o}C



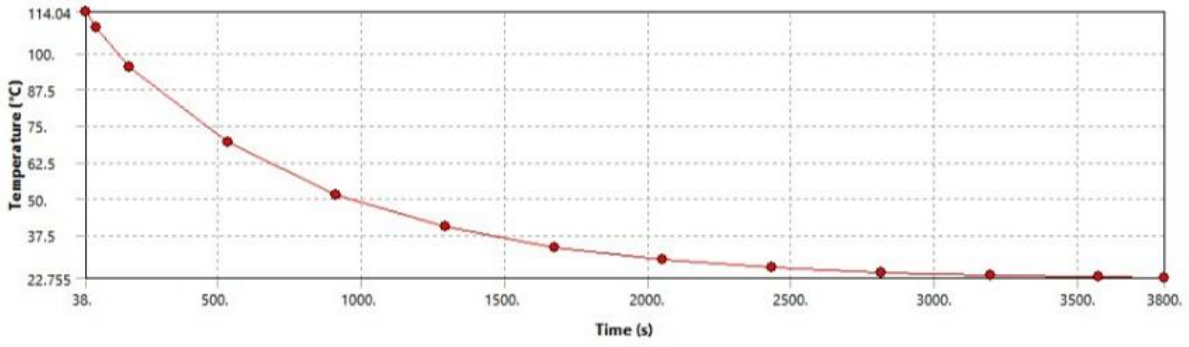
Graph. 1 (c): At convection coefficient of 1.5×10^{-5} W/mm^2 ^{o}C



Graph. 1 (d): At convection coefficient of 1.75×10^{-5} W/mm^2 ^{o}C



Graph. 1 (e): At convection coefficient of 2×10^{-5} W/mm^2 ^{o}C



Graph. 1 (f): At convection coefficient of 2.2×10^{-5} W/mm^2 ^{o}C

The graph for natural convection heat transfer (cooling rate) with respect to time and convection coefficients are shown in figures.

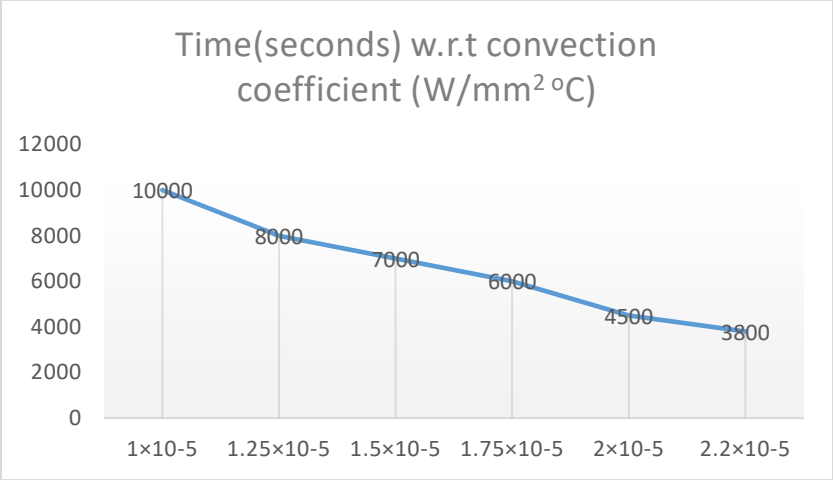


Fig. 6: Plot

Conclusion

In this paper, natural convection heat transfer is used for cool down the steel cylinder by using ANSYS Transient Thermal. For this purpose, a steel cylinder is designed having radius of 10 mm and depth 40 mm. The temperature of the steel cylinder is given 20^{o}C and ambient temperature of the surrounding was given 120^{o}C. When we apply convection coefficient of 1×10^{-5}W/mm^{2o}C, the steel cylinder starts to cool with passage of time. The results show that the temperature decreases earlier from the center as compared to the edges of the cylinder. The temperature decreases from 120^{o}C to 22.357^{o}C in 10000 seconds. These results show that cooling rate is rapid at the start of simulation and decrease gradually with increase in time. When we apply our final convection coefficient of 2.2×10^{-5} W/mm^{2o}C, the temperature decreases from 120^{o}C to 22.755^{o}C in 3800 seconds. These simulations show that heat transfer (cooling rate) of steel cylinder has directly related to the convection heat coefficient.

Author's Contribution: M. A. M. Shahid. conceived the idea, designed the simulated work, did the acquisition of data, executed simulated work and wrote the basic draft. M. A. M. Shahid, M. T. Khan and F. Javaid did data analysis or analysis and interpretation of data and did the language and grammatical edits or critical revision.

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Fuzzy Mathematical Analysis of Blood flow through Brachial Artery

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Original Research Article

ABSTRACT

Hypertension is a common disease that can be caused by a number of factors. A variety of methods, including Doppler Ultrasonography, can be used to detect hypertension, which is aided by High Blood Pressure. In this paper, Fuzzy value of speed is 12 cm/s, and corresponding Mamdani's value is 11.8 cm/s with 0.2 difference. Fuzzy value of flow rate is 14.5 mL/min, and corresponding Mamdani's value is 14.5 mL/min with 0.0 difference. Our Fuzzy Mathematical analysis provides values of Blood Speed with 1% margin of error as well as values of Blood Flow within 0% margin of error. The fuzzy logic approach is ideal for combining human expert knowledge with pre-existing numerical data. Fuzzy logic systems use human reasoning and decision-making to generate reliable output even when precise information is unavailable. In the case of biological systems, mathematical modelling is extremely complex, but fuzzy linguistic rules have been shown to aid in the resolution of complexity.

Keywords: Hypertension, Doppler Ultrasonography, Fuzzy logic systems

Introduction:

Hypertension, more frequently known as High Blood Pressure, affects around 1 billion people with an estimated annual death rate of 10,000,000 by the condition worldwide. Hypertension is defined as increased blood pressure in the body [1]. For a vivid understanding, blood pressure is the force exerted by blood, which comprises red blood cells, white blood cells, plasma, etc., on the walls of arteries, the major blood vessels that carry blood away from the heart and to the organs. Hypertension can be classified into two types: essential hypertension (primary hypertension) and inessential hypertension (secondary hypertension) [2].

Essential Hypertension is the more common form of hypertension, affecting 85% of all patients suffering from High Blood Pressure. Essential hypertension is the type of hypertension with no observable secondary cause [3]. Although essential hypertension has no observable cause, there are certain factors that increase its probability of occurring. Certain mechanisms are caused

by Obesity such as the activation of the sympathetic nervous system, which has been found to cause hypertension. Excessive Alcohol Intake can also increase hypertension risk as it is known to increase blood pressure over time [4]. Aging also has a positive relation with hypertension risks because as we grow older, our arteries tend to stiffen out, which can result in decreased vascular compliance. Furthermore, renin elevation i.e. high renin levels have been found to cause increased sodium retention which can lead to increased blood pressure. Moreover, a poor exercise routine is known to have a positive correlation with increased blood pressure. Vitamin deficiency, specifically Vitamin D deficiency, is also observed to be related to cardiovascular diseases, increasing both systolic and diastolic pressure [5]. However, there is also a factor that is not in our control: Genetics. It is known that one is more probable to suffer hypertension if he/she has a family history of hypertension. Furthermore, African-Americans are also more likely to suffer from hypertension [6].

Secondary Hypertension, on the other hand, is much less common, affecting only 15% of all patients suffering from high blood pressure [7]. By definition, it has an identifiable cause. These causes may include kidney disease, which may increase renin levels, and as we know, renin elevation may cause increased blood pressure. Adrenal Disease may also cause Hypertension when adrenal glands produce an unbalanced number of hormones which can cause various other diseases, leading to increased blood pressure. Furthermore, Hyperparathyroidism may also play a role in Hypertension as Parathyroid glands overproduce hormones to regulate calcium levels, causing increased blood pressure. Furthermore, abnormal thyroid functions and certain medications are found to be positively correlated with increased blood pressure [8]. Such medications include Hormonal contraceptives, Antidepressants, Immune system suppressants, Decongestants, Acetaminophen, etc. [9].

Hypertension, like many other diseases, have stages as well. Normal blood pressure is less than 120mmHg/80mmHg (Systolic BP/Diastolic BP). Stage 1 Hypertension has a blood pressure of approximately 135mmHg/85mmHg whereas stage 2 Hypertension has a blood pressure of greater than 145mmHg/90mmHg. Typically, both systolic and diastolic blood pressure have a positive correlation. However, sometimes, only one of the two blood pressures rise. This is called Isolated Diastolic Hypertension, where only the diastolic blood pressure rises, and Isolated Systolic Hypertension, where only the systolic blood pressure rises [10].

But why is hypertension so detrimental to begin with? High Blood Pressure causes the wear and tear of endothelial cells that line the interior of blood vessels. This results in narrowed arteries which may lead to blockades by built-up fat or even the formation of an aneurysm [11]. In specific, large arteries have a 15-40% increase in intima-media thickness and as time passes, they lose their elasticity over time, becoming stiff, which can cause atherosclerosis. For small arteries, hypertension leads to a greater media thickness, a decrease in the lumen, and an increased media to lumen ratio. There is no significant change in the amount of total wall tissue. As a result, there is an increase in vascular resistance and impairs the regulation of blood flow. Hypertension also can cause many diseases to major organs including coronary heart disease, glomerulosclerosis, and a transient ischemic attack [12].

Therefore, a quick, accurate, and reliable method of identifying Hypertension is very important before any crucial damage takes place. For calculating the blood flow rate, we will be using Doppler Ultrasonography on the Brachial Artery [13]. Before going into how we will do this, we will first explain the physics behind this method of ultrasound. The fundamental physics

of Doppler Ultrasonography is, as the name states, the Doppler Effect. By definition, Doppler Effect is a shift in any wave, e.g. sound or light, as the distance between the wave source and observer changes. To better visualize this effect, let's take a scenario of a duck in a pond. As the duck moves up and down slightly while staying in the same position relative to the surface of the pond, observers can see a ripple effect or circular waves going away from the duck [14]. As the duck moves, the waves in the direction of movement have a higher frequency and vice versa. For a police car, the siren becomes progressively louder as it is approaching you. Although this seems very intuitive and common sense, it is a major component of physics [15].

We have explained the fundamental principle behind Doppler Ultrasonography, and now we will explain how it is done. A transducer (a device that we are using to emit sound waves at frequency F_E) is lightly placed on the skin and a series of pulses is transmitted to detect movement of blood, which consists of red blood cells, white blood cells, plasma, etc. [16]. The transducer, using a microphone, amplifies the returning sound wave and stores its frequency F_R. The transducer, connecting to a computing device, automatically finds the change in Doppler shift F_D, or change in frequency, by the formula:

$$F_D = F_E - F_R.$$

The velocity of blood can be calculated using the formula:

$$F_D = \frac{2F_T cos(\theta)}{c},$$

where c is the speed of sound in tissue and θ is the angle of insonation, the angle between the transmitted beam of sound and the blood flow direction - which is optimal at 45 - 60 degrees [17].

There are two most common types of Dopplers: Color Doppler & Spectral Doppler. Color Dopplers create an image of the blood vessel and the information from the doppler ultrasonography. This information is fed into an algorithm to produce colors on each pixel of the image. Typically, the color red shows that blood is moving away from the transducer and the color blue shows blood moving towards the transducer. The shade of red or blue determines the intensity of blood flow which can be measured using a color scale [18].

Spectral Dopplers, on the contrary, produce a graph or spectral waveform from the information from the Doppler ultrasonography using Fourier analysis. The spectrum is the doppler shift displayed against time. Through proper analysis of the spectrum, we can obtain important characteristics of vascular flow which include the Peak Systolic Velocity (PSV) which is the greatest velocity blood travels in a vessel during systole [19], the End Diastolic Velocity (EDV) which is the velocity, and the end of the cardiac cycle, just before the PSV, the Systolic/Diastolic Ratio (S/D), the acceleration index which is the gradient of the systolic upstroke, the volume flow, the Pulsatility Index (PI), and the Resistivity Index (RI) which is used alongside PI to assess the resistance in a vascular system. The Resistivity and Pulsatility Index can be calculated from the following formulae respectively [20].

$$RI = \frac{PSV - EDV}{PSV}$$

$$PI = \frac{PSV - EDV}{Vmean}$$

Due to these values, along with added sensitivity to change in frequency, Spectral Doppler is the preferred method to calculate blood flow.

The arterial blood velocity ranged from 4.9 cm/sec to 19 cm/sec, whereas venous blood flow was meaningfully slower, ranging from 1.5 cm/sec to 7.1 cm/sec. Hence, blood flow rates of 3.0 ml/min to 26 ml/min in arteries are obtained when the corresponding vessel diameters range from 800 micro meter to 1.8 milli meter [21]. The frequency 2 MHz to 200 MHz, is required to measure blood flow rate in the artery [22]. In conditions that are nonlinear and time-dependent, however, fuzzy based methods work well with fast convergence and less complexity. Fuzzy logic is the opposite of Boolean logic. Boolean is binary, meaning two: either 1 or 0, or True or False. Fuzzy logic, however, gives the degree of truths, such as 0.8, 0.2 and 0.5. This is advantageous to algorithms since they can produce outputs with more precise and broader range of data, instead of a crisp value. As fuzzy logic clone's human decision making, it is effective in problems with no clear input. Furthermore, it is also much easier to program. For incorporation of human expert knowledge and already available numerical data, fuzzy logic approach is highly suitable. Fuzzy logic systems utilized human reasoning and decision-making; these systems are based on IF-THEN rules to develop reliable output even without the availability of precise information [23, 24]. In the case of biological systems, mathematical modeling is highly complicated, but linguistic rules of fuzzy prove to help solve complexity [25].

S. Tayyab et al. used a fuzzy logic control system to perform simulations for flow control in straight microchannels. The results show that fluid flow systems can be developed precisely under different channel widths and varied applied pressure [26]. M. Javaid et al. used FLC for estimation of flow rate and velocity of ascending and descending sinusoidal microchannel to be utilized as replacement n varicose vein for maintaining blood flow [27, 28]. M. W. Ashraf et al. performed fuzzy simulations to manipulate the pore diameter of Anodized aluminum oxide membrane for successful applications in biotechnology [29]. Different researchers use ANSYS and Fuzzy simulation for different researches and get very useful results [30-36].

In this paper, fuzzy logic controller in MATLAB is used for simulation and analysis of fluid flow speed and flow rate. Mamdani's mode is used for calculation of the results and simulated and calculated results are then compared to check the reliability of results.

Fuzzy simulation method

The block Simulink of fuzzy represents the two input variables (length and radius) against two outputs (speed and flow rate) for the fussy analysis as shown in figure 1. Three membership functions are assigned to each input and output variable as shown in figure 2, 3, 4 and 5. The range of each input is defined by using literature study and the range of output variables is defined by using the following calculations:

$$F_D = \frac{2F_T\, v \cos(\theta)}{c} \text{----------(1)}$$

The flow rate is given by:

$$Flow\ rate = \frac{1}{4}\pi d^2 v - - - - - - (2)$$

Where d = diameter and v = speed

Table 1. Calculations with minimum, average, and maximum values of variables.

Value	Frequency (MHz)	Diameter (mm)	Speed cm/s	Flow rate mL/min
Mf1	2	0.008	4.9	3
Mf2	101	0.904	11.95	15
Mf3	200	1.8	19	26

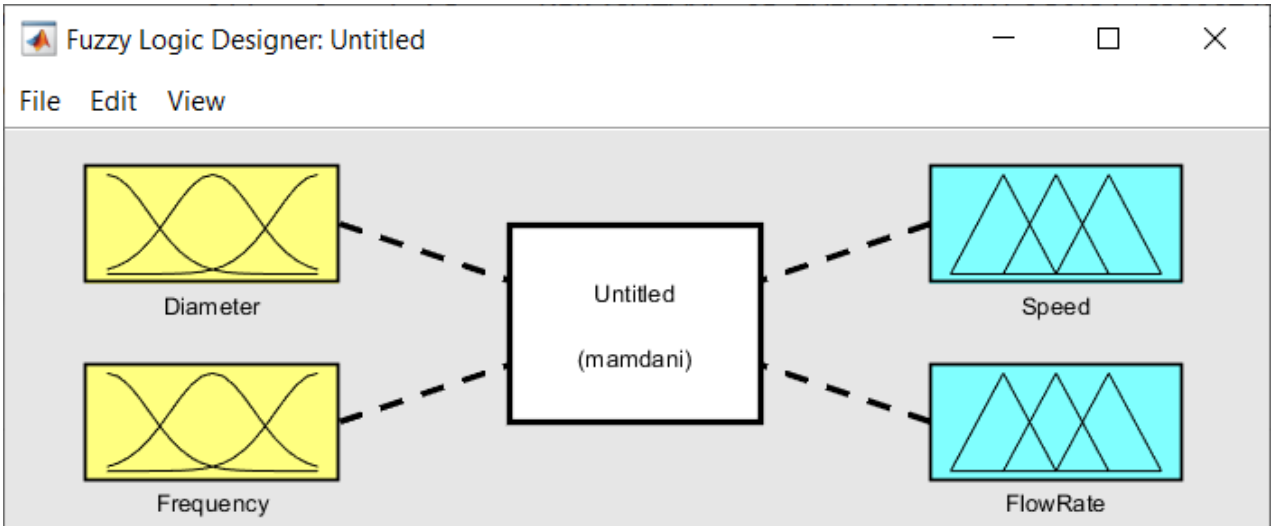

Fig. 2: Fuzzy interface of inputs and corresponding outputs

There are two inputs in the FLC: diameter and frequency. Using these, there are two outputs: Speed and Flow rate.

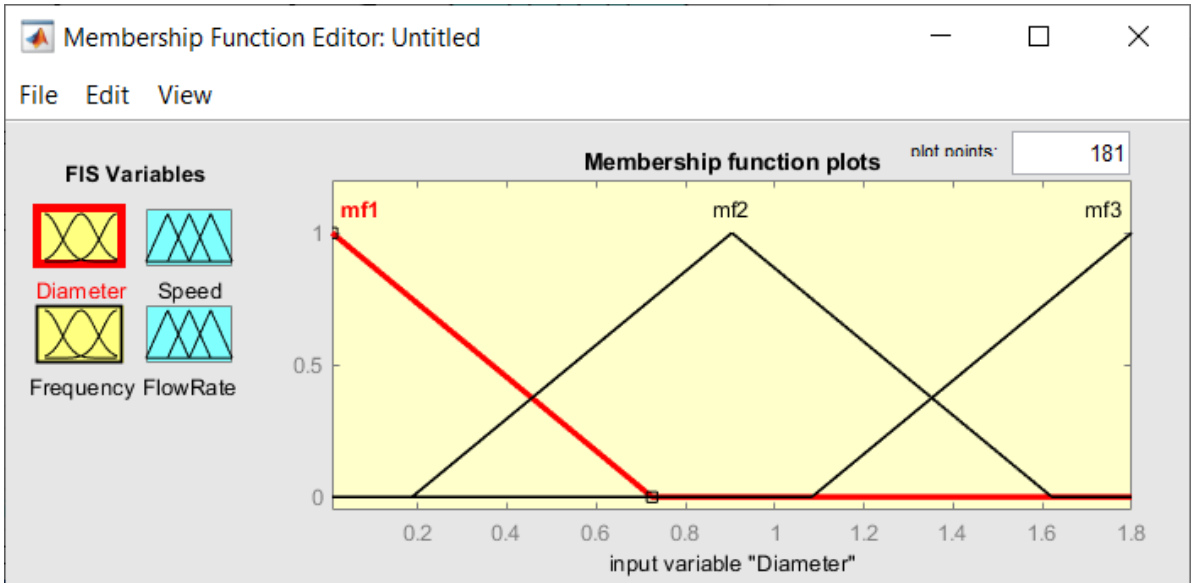

Fig. 3: Membership function for Input "Diameter"

There are three sections to the Membership function for “diameter”: mf1, mf2, and mf3. The range is 0.008 mm to 1.8 mm.

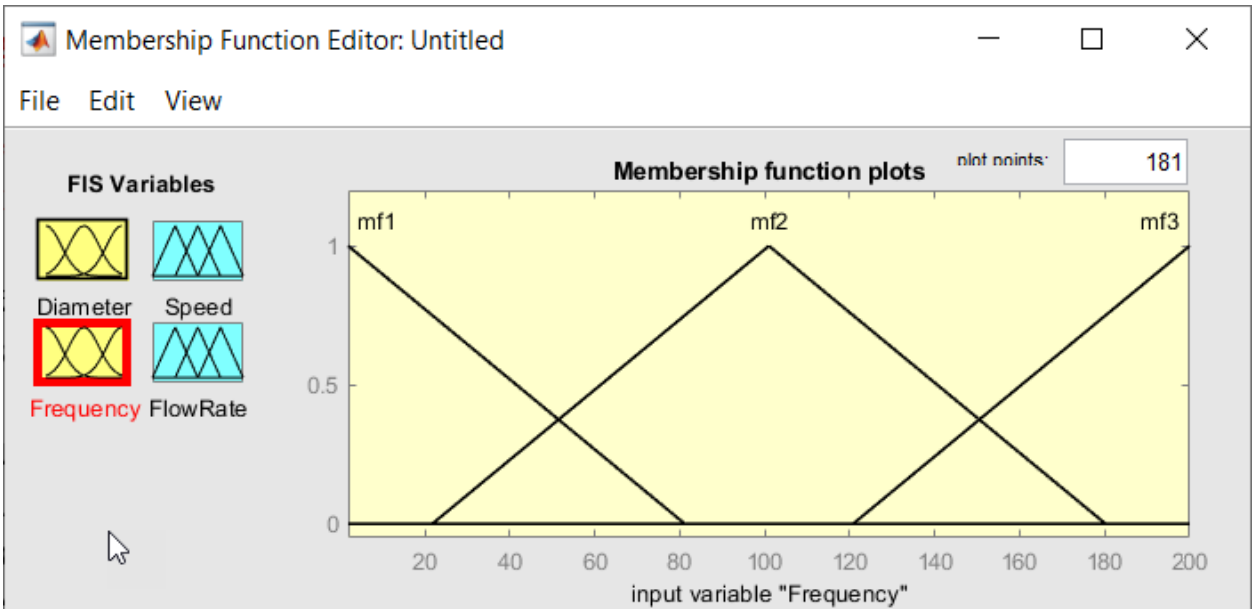

Fig. 4: Membership function for Input "Frequency"

There are three sections to the Membership function for “frequency”: mf1, mf2, and mf3. The range is 2 to 200 MHz.

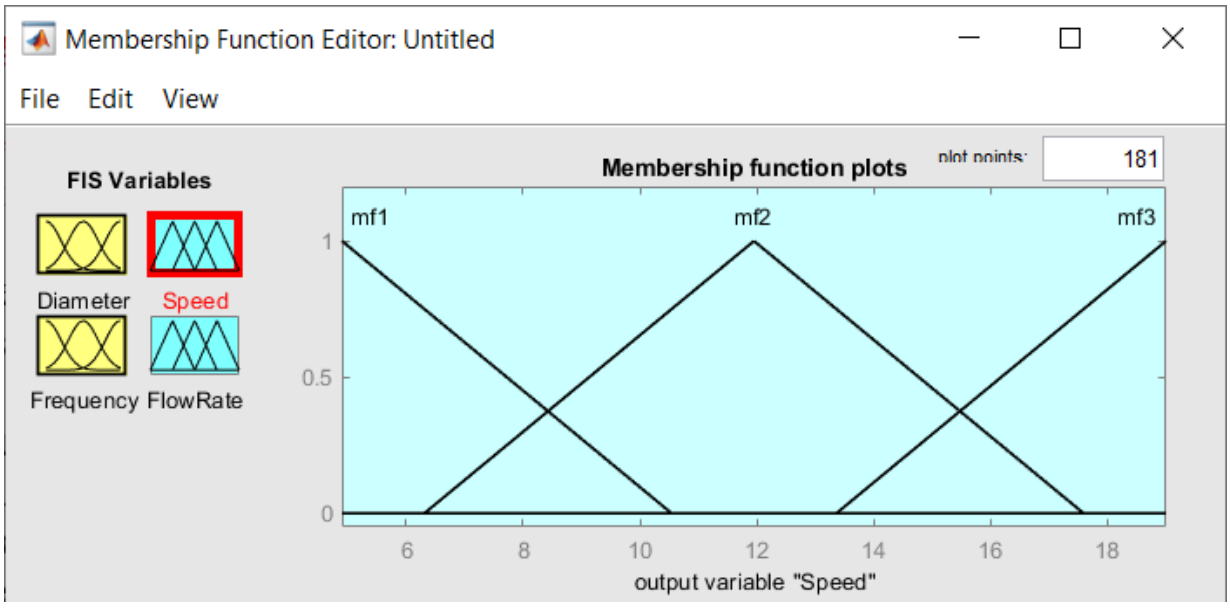

Fig. 5: Membership function for output "Speed"

There are three sections to the Membership function for “speed”: mf1, mf2, and mf3. The range is 4.9 cm/s to 19 cm/s.

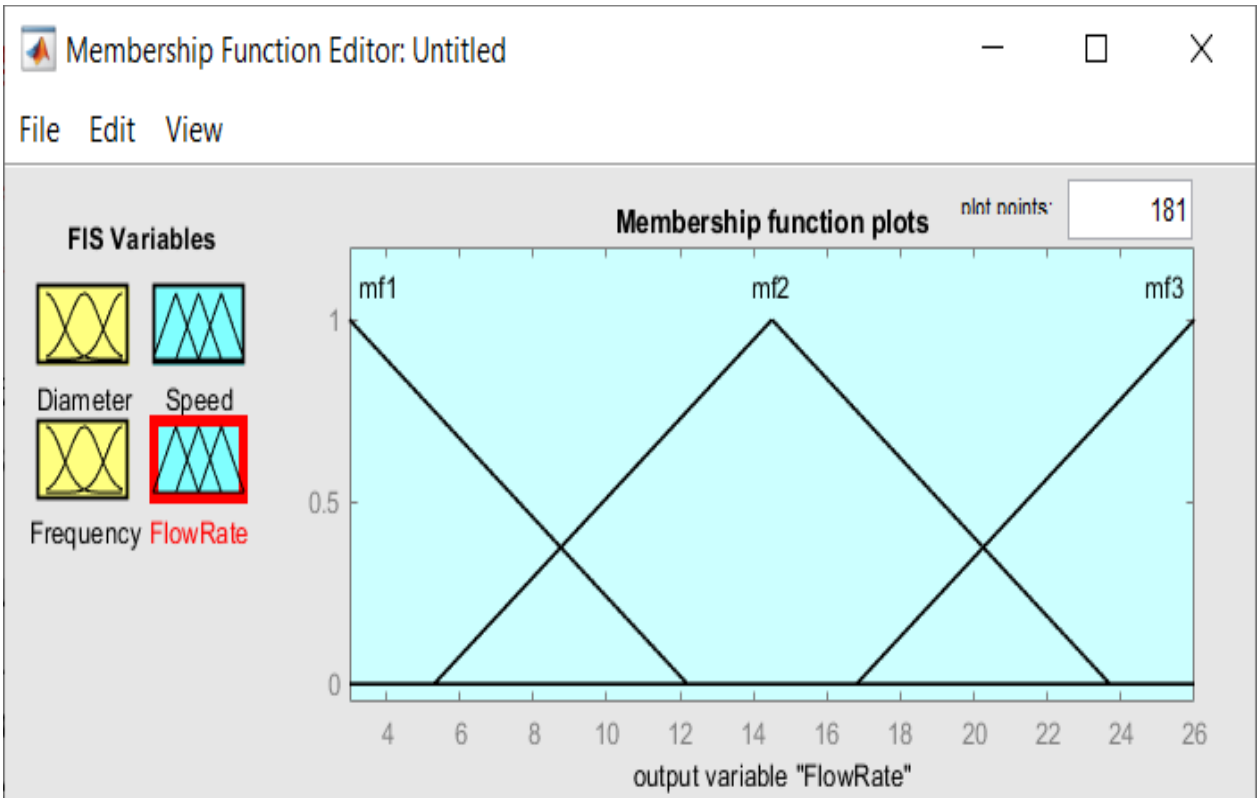

Fig. 6: Membership function for output "Flow rate"

There are three sections to the Membership function for “flow rate”: mf1, mf2, and mf3. The range is 3 mL/min to 26 mL/min. Using Mamdani’s model $3^2 = 9$ rules are defined for simulations as given in rule editor. The rule viewer graph from fuzzy analysis is given in Figure 12. From this graph the crisp values of each input are noted for calculation of output values using Mamdani’s model calculations:

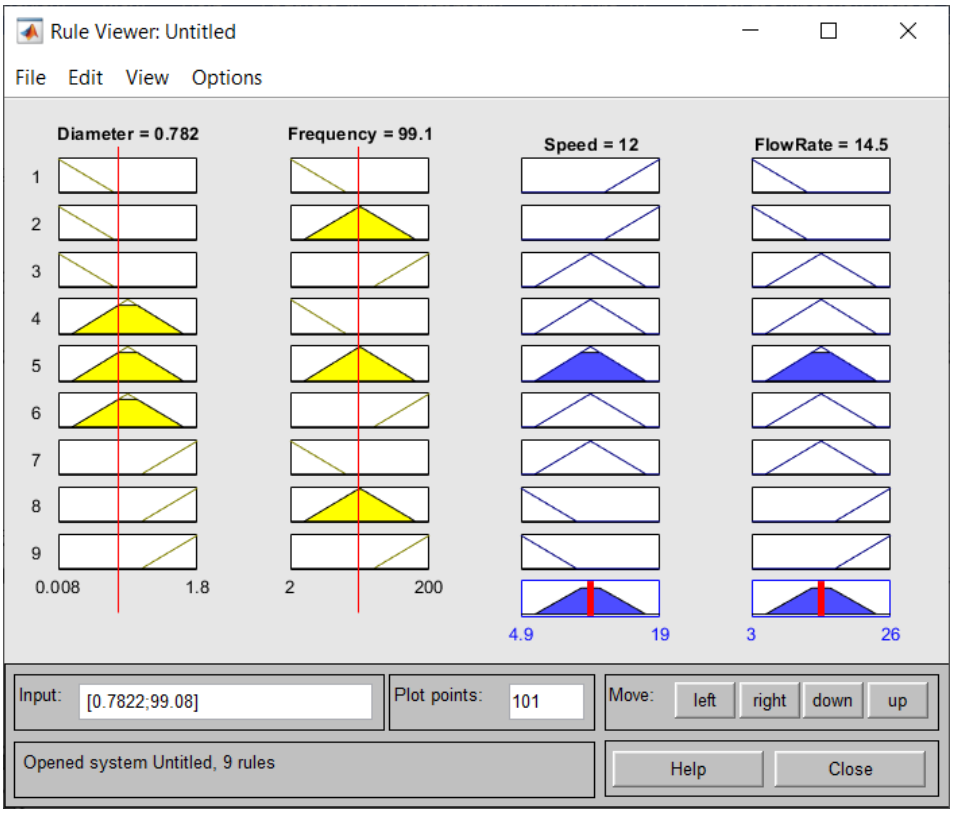

Fig. 7: Rule viewer for input and output crisp values calculation

In this Figure 7, with an input of diameter = 0.782 mm and frequency = 99.1 MHz, the output is Speed = 12 cm/s and Flow Rate = 14.5 mL/min.

Results and Discussion

The 2D and 3D graphs for inputs versus outputs to show the variations in output are obtained from fuzzy analysis. There is a decreasing relationship between diameter and speed. When the speed is 16, the diameter is 0.1. When the speed is 13, the diameter is 1.5. When the speed is 10, the diameter is 1.5. There is an inverse relationship between speed and diameter. There is an increasing relationship between flow rate and length. When the flow rate is 10, the diameter is 0.3. When the flow rate is 15, the diameter is 1. When the flow rate is 20, the diameter is 1.5. There is a direct relationship between flow rate and diameter.

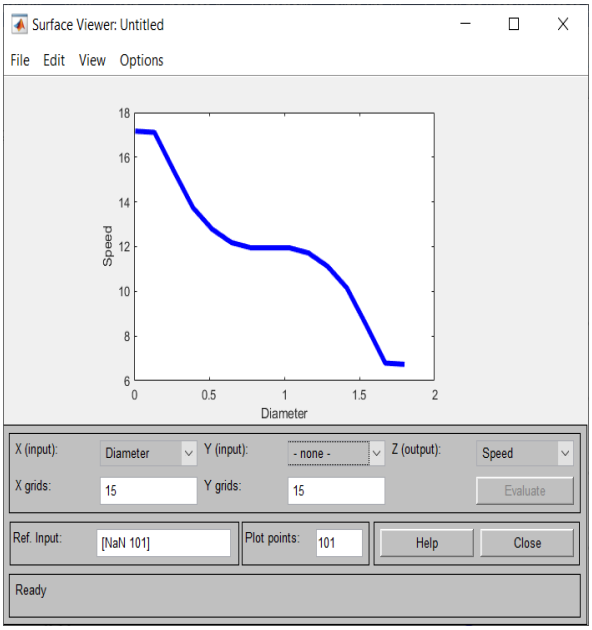

Fig. 8: 2D graph for speed and diameter

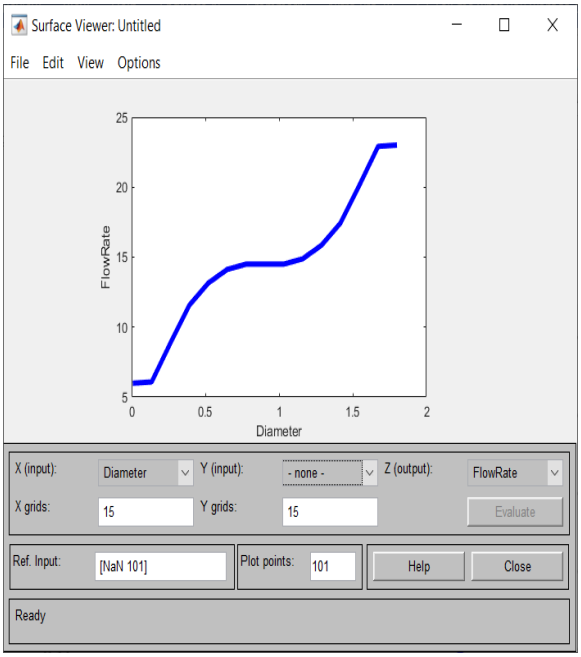

Fig. 9: 2D graph for Flow rate and diameter

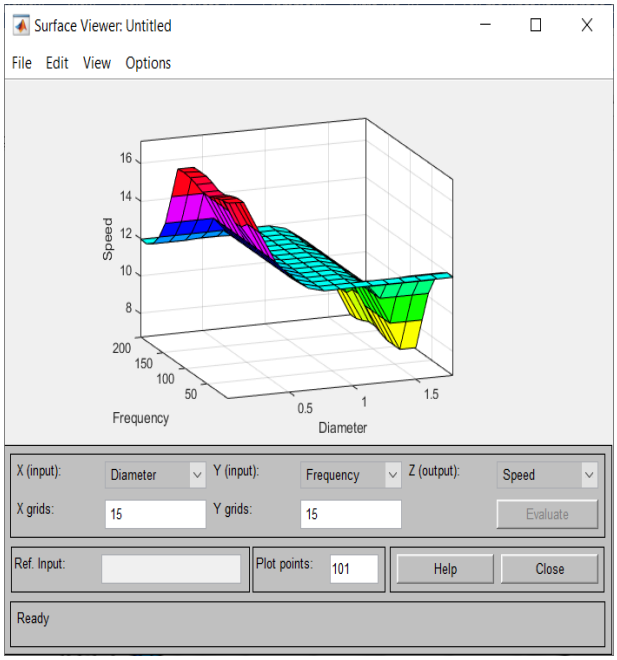

Fig.10: 3D graph between diameter, frequency and speed

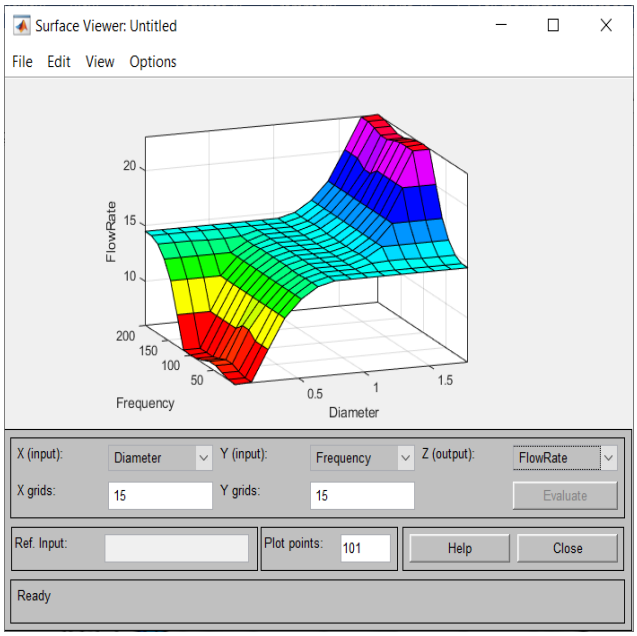

Fig. 11: 3D graph between diameter, frequency and flow rate

Mamdani Mathematical Calculations for speed and flow rate

Here, Mamdani's method is used for the verification and authentication of Fuzzy Simulation. Now for speed, Membership function calculations using crisp values

$$K1 = 1.8 - \frac{0.8}{1.8} = 0.55$$

$$K2 = 1 - K1 = 0.45$$

$$K3 = 200 - \frac{150}{200} = 0.25$$

$$K4 = 1 - K3 = 0.75$$

Table 2. Calculations of speed

Length	Radius	Speed	Minimum Membership function value	Min. Value (Mi)	Singleton value (Si1)	Speed Mi x Si1
Mf1	Mf1	Mf3	K1^K3	0.25	0.19	0.0475
Mf1	Mf2	Mf3	K1^K4	0.55	0.19	0.1045
Mf1	Mf3	Mf1	K2^K3	0.25	0.004	0.001
Mf2	Mf1	Mf1	K2^K4	0.25	0.004	0.001

$$\Sigma Mi = 1.3 \quad \text{and} \quad \Sigma (Mi \times Si1) = 0.154$$

$$\text{Expression of Mamdani's Model} = \frac{\Sigma (Mi \times Si1)}{\Sigma Mi} * 100$$

$$= \frac{(0.154)}{1.3} * 100$$

$$= 11.8$$

Here, Mamdani's method is used for the verification and authentication of Fuzzy Simulation. Now for flow rate, Membership function calculations using crisp values

$$K1 = 1.8 - \frac{1.2}{1.8} = 0.33$$

$$K2 = 1 - K1 = 0.67$$

$$K3 = 200 - \frac{90}{200} = 0.55$$

$$K4 = 1 - K3 = 0.45$$

Table 3. Calculation of flow rate

Length	Radius	Flow rate	Minimum Membership function value	Min. Value (Mi)	Singleton value (Si2)	Flow rate Mi x Si2
Mf1	Mf1	Mf2	K1^K3	0.33	0.145	0.04785
Mf1	Mf2	Mf2	K1^K4	0.33	0.145	0.04785
Mf1	Mf3	Mf2	K2^K3	0.55	0.145	0.07975
Mf2	Mf1	Mf2	K2^K4	0.45	0.145	0.06525

$\Sigma \text{Mi} = 1.66$ and $\Sigma (\text{Mi x Si2}) = 0.24071$

Expression of Mamdani's Model $= \frac{\Sigma (\text{Mi} \times \text{Si2})}{\Sigma \text{Mi}} * 100$

$$= \frac{(0.24071)}{1.66} * 100$$

$$= 14.5$$

The difference between simulated and calculated results of both outputs is zero that proves that the results obtained are reliable for future applications.

Conclusion

In this paper, Fuzzy method has been used for simulation. Fuzzy value of speed is 12 cm/s, and corresponding Mamdani's value is 11.8 cm/s with 0.2 difference. Fuzzy value of flow rate is 14.5 mL/min, and corresponding Mamdani's value is 14.5 mL/min with 0.0 difference. Our Fuzzy Mathematical analysis provides values of Blood Speed with 1% margin of error as well as values of Blood Flow within 0% margin of error. As a result, our proposed method, alternate to Doppler Ultrasonography, will decrease expense financially and in terms of time while keeping our data extremely accurate. Results are shown in Table 4 and 5 below.

Table 4: Calculation for speed

Speed	Value (cm/s)
Fuzzy Value	12
Mamdani Value	11.8
Difference	0.2
Percentage Error	1.6%

Table 5: Calculation for flow rate

Blood Flow	Value (mL/min)
Fuzzy Value	14.5
Mamdani Value	14.5
Difference	0.0
Percentage Error	0.0%

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FUZZY BASED APPROACH FOR THE PARAMETRIC ESTIMATION OF THE MEMS BASED THERMO PNEUMATIC MICRO PUMP

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ABSTRACT

Over the last few decades, technological advancements and the tendency toward miniaturization have resulted in the development of a new subject known as micro-electro-mechanical systems (MEMS). MEMS have many applications but our focus in this research was on MEMS-based thermopneumatic micro pump. It consists of a chamber, loaded with vapors or solution, a diaphragm, and a temperature control system. It has many advantages like low power consumption while maintaining high performance and accurate dose control. MATLAB fuzzy logic controller (FLC) is used for the parametric estimation of the MEMS-based thermopneumatic micropump. The effect of voltage and frequency applied on the micropump were studied on the back pressure and flow rate. The increase in voltages and frequency were decreased the back pressure and fluid flow rate. Similarly, with a decrease in voltages and frequency were increased the back pressure and fluid flow rate. The difference between the MAMDANI calculated value and the simulated value from the rule viewer is 1.61% for both the output of back pressure and flow rate.

Keywords: MEMS, Thermopneumatic micropump, Fuzzy logic controller

Introduction:

Many micropumps have already been created utilizing various techniques for use in MEMS. The thermopneumatic technique is one of the various techniques, significant in the categorization of mechanical micropump [1]. Looking for the benefits of the thermopneumatic

actuator it consists of compact size and cheap expense as well as low energy efficiency while maintaining high performance and accurate dose control [2]. In addition, it can easily manufacture by the lithography method. This kind of actuator has a chamber, loaded by vapors or solution, diaphragm and the temperature control system [3]. This system includes the heater and air conditioning module this will alter the pressure within the air chamber as a result solution will be pumped back and forth between pump chamber using input and exit valves [4]. In response, the diaphragm moves with a moderate voltage level. When temperature rises with the heater, deforming the diaphragm and pressing the pump chamber in the process. In cooling process, the lowering temperature will lower the pressure exerted on the diaphragm. Therefore, the diaphragm returns to its normal position [5]. This change in pressure in the micropump serve as the metrics for analyzing the performance. The quantity of solution pump is primarily determined by displacement of diaphragm, that in turn determined by the torque produced by the actuators [6]. The change in pressure is described by the following equation (1).

$$\Delta P = E(\beta \Delta T - \frac{\Delta V}{V}) \quad (1)$$

Where ΔP represents the change pressure, β represents thermal expansion, ΔT represents the temperature change, and $\frac{\Delta V}{V}$ represents a percentage of volume change [7]. The resonance frequency is governed by the stiffness characteristics of material which in turn influenced by geometrical characteristics such as thickness and area of the micropump [8]. The diagrammatic representation of the thermopneumatic micropump is shown below.

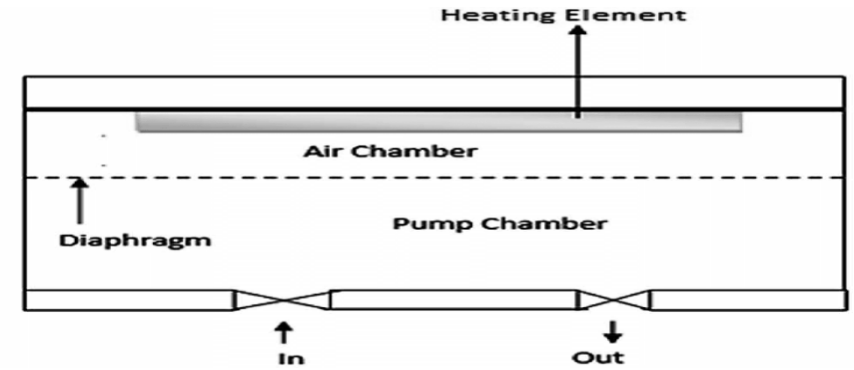

Fig. 1. Diagrammatic representation of thermopneumatic micropump [9]

The pump chamber, on the other hand, causes heat to build up in the chamber. When heat production is not an issue, thermopneumatic pump is a good choice for the application Furthermore, the low thermal response is an inherent characteristic of this pump [10]. Thermopneumatic micropumps has a lengthy thermal time constant, which has restricted its application. As a result, Woias et al in 2005 described the maximum frequency of thermopneumatic pump to be around 50 Hz [11]. Van De Pol et al. (1990) was the first researcher reported the thermopneumatic micropump in which fluid velocity was measured at 34 L/min and temperatures reached almost 30 degrees Celsius at 6 V [9]. The efficiency of the system decreases above 100Hz as thermopneumatic micropump may not be capable to cool enough the fluid [12]. The researchers of 2015 have demonstrated the thermopneumatic micropump without using the mechanical parts although this pump is classified under the mechanical pumps. Parthasarathy et

al. demonstrated that such pump operates based on Charles Law, which specifies that volume is direct proportion to the temperature, the pressure remain constant [13]. Chin and Tan et al. uses the thermopneumatic actuation method for their applications as Biomedical and microfluidic devices respectively. Abi-Samra et al. represented the TPP for the application as centrifugal microfluidic disc platforms [14]. The LC resonator driven TPP was constructed by Chee et al. simulated findings showed that the heat chamber reached 46.7°C in very little time of 40s following activating the micro heater [15-16].

Fuzzy Logic Controller (FLC) is used for simulation because it provides a very valuable flexibility for reasoning[17]. Fuzzy logic is used to handle fractional or partial truths, where the truth value may be completely true or false or may be in between of both. Relative importance of precision is the core of the fuzzy logic. It is a technique to impose human-like thinking into a controlled experiment[18][19].

In this work, a fuzzy logic controller was used to perform parametric estimate for the development of a MEMS-based thermopneumatic micropump. When an electric voltage is provided to the heater, the temperature of the air inside the cavity rises, which causes the diaphragm to deflect. The pressure is created by the diaphragm deflection, and this pressure is responsible for the fluid flow through the valve. The increase in voltages and frequency will decrease the back pressure and fluid flow and decrease in voltages and frequency will increase the back pressure and fluid flow.

Fuzzy system design:

To obtain exact output variable data based on the change in given inputs, input variables have been defined in the fuzzy logic controller. Voltages, frequency, back pressure, and fluid flow are the two input and output variables on the fuzzy inference editor, as illustrated in Fig.2. It's crucial because fuzzy logic has a wide range of values between 0 and 1, which makes it almost optimal.

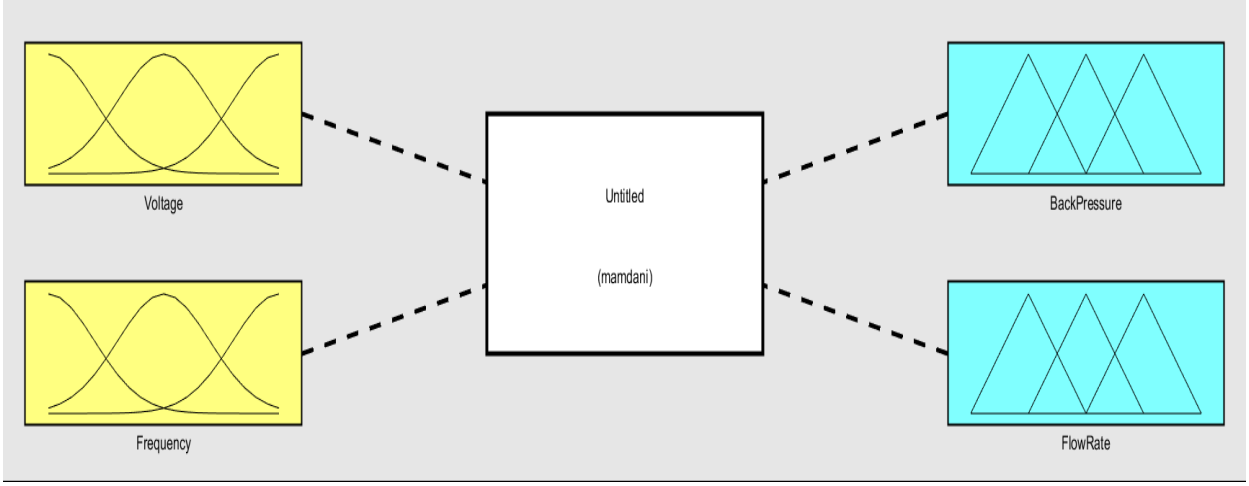

Fig.2. Fuzzy Inference system for the thermopneumatic micropump

The input and output variable graphs were created using the MATLAB membership function. A graph has been generated for each of the two unique entities. Figures 3-6 show the graphs for the input voltage and frequency, as well as the output back pressure and flow rate. The range for the input parameters voltage and frequency were 1-30V and 1-20Hz, respectively. The

range for the output parameters back pressure and flow rate were 1-6kPa and 1-40ul/min, respectively.

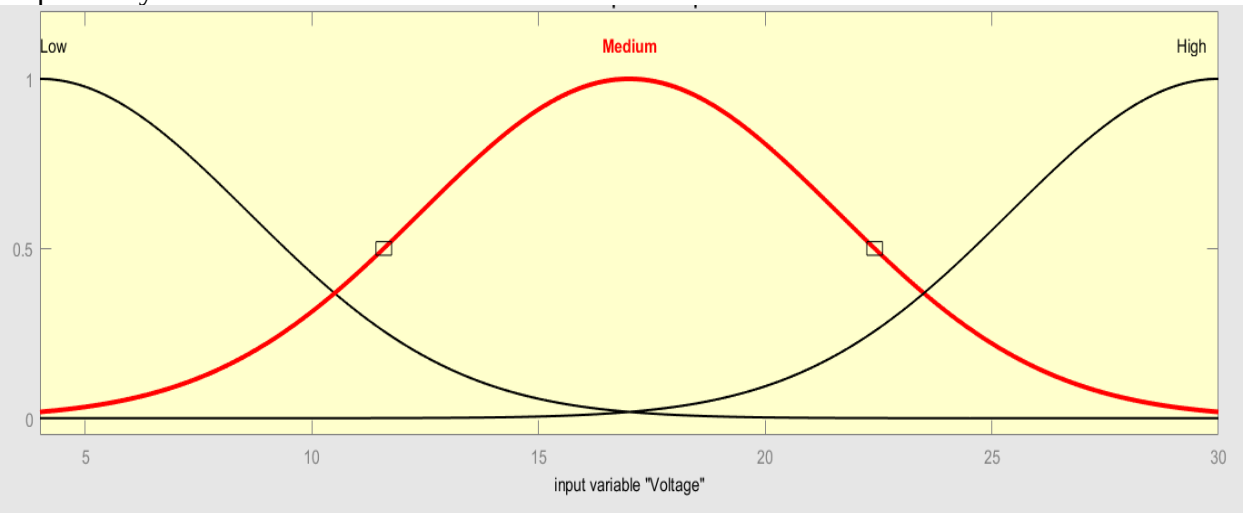

Fig. 3. Membership function graph showing voltage 1(1-30V)

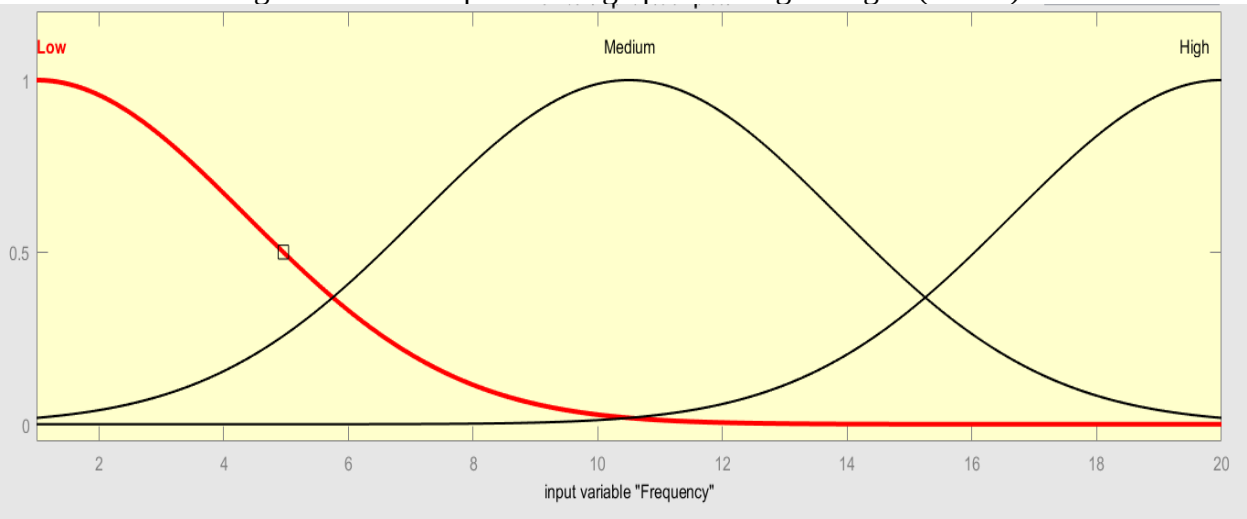

Fig. 4. Membership function graph showing frequency(1-20Hz)

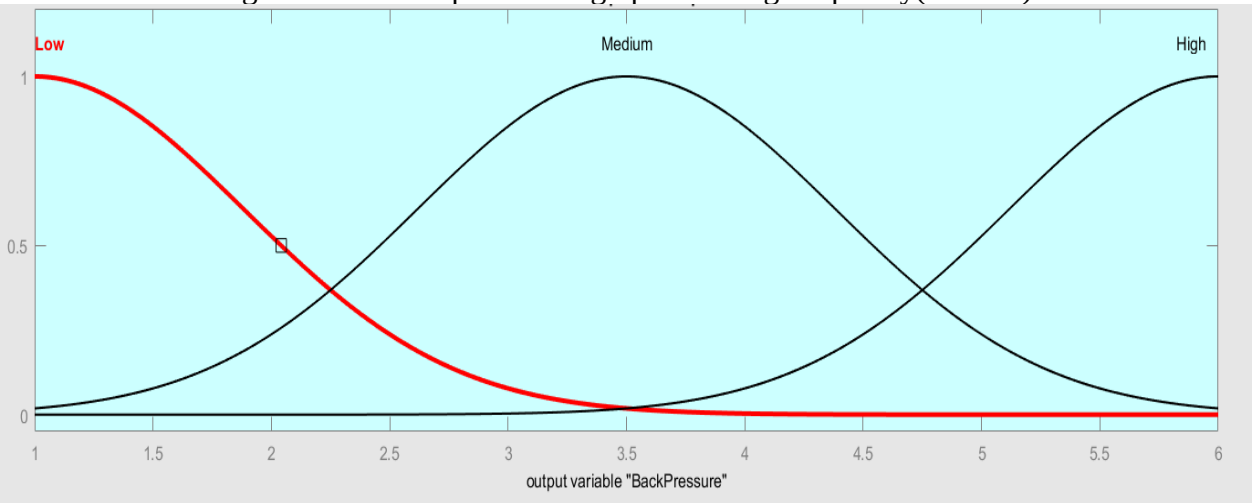

Fig. 5. Membership function graph showing Back pressure (1-6KPa)

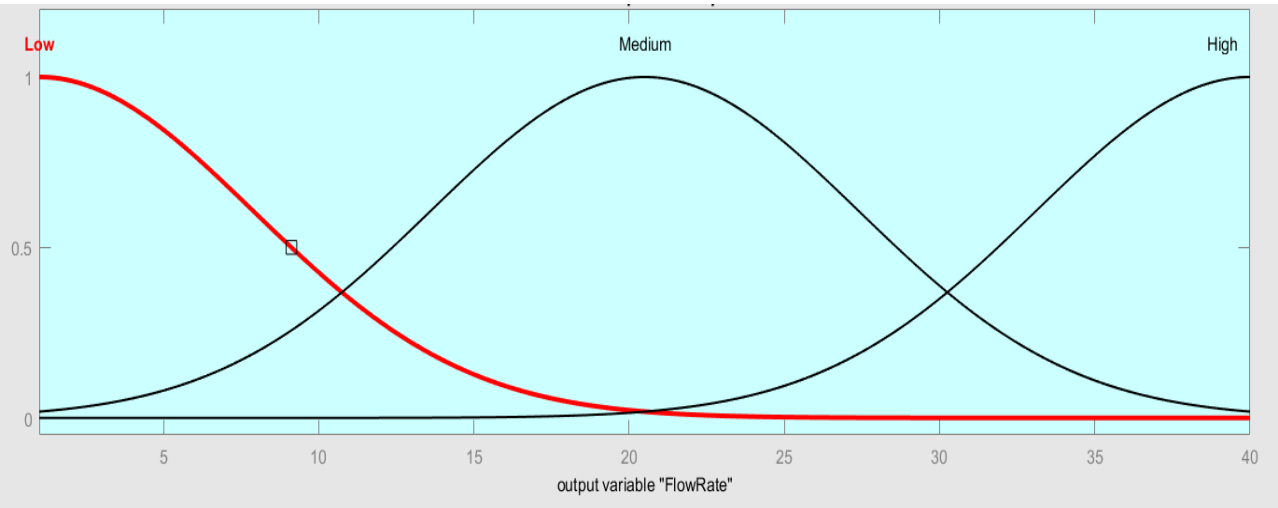

Fig. 6. Membership function graph showing Flow Rate (1-40ul/min)

There are a total of 9 ($3^2 = 9$) rules for designing the fuzzy logic controller because there are two input variables and three membership functions. The input linguistic variables are these nine membership functions, and each set has a corresponding output linguistic variable. The Hagen–Poiseuille equation is used to define the output linguistic variable. These rules are used to generate the MATLAB FLC simulation results. The defined rules are shown in Table I.

Table I: Rules selected for MATLAB fuzzy logic simulations

Voltage(V)	Frequency (Hz)	Back Pressure (KPa)	Flow Rate(ul/min)
Low	Low	High	High
Low	Medium	High	High
Low	High	Medium	Medium
Medium	Low	Medium	Medium
Medium	Medium	Medium	Medium
Medium	High	Low	Low
High	Low	Medium	Medium
High	Medium	Low	Low
High	High	Low	Low

3D graphs are investigated using the rules. We have a three-dimensional graph as shown in Fig. 7 and 8 in which voltage and frequency are the two inputs and back pressure and flow rate is the output respectively.

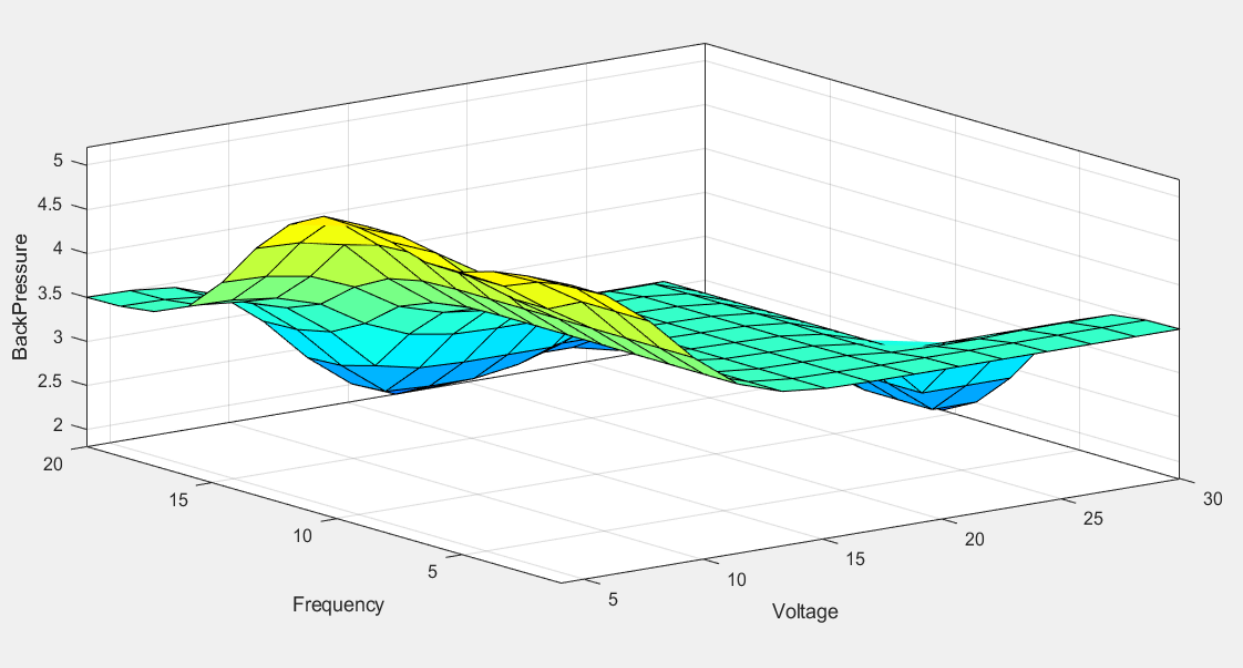

Fig. 7. 3D graph between the input voltage and frequency applied to the micropump with respect to the output back pressure.

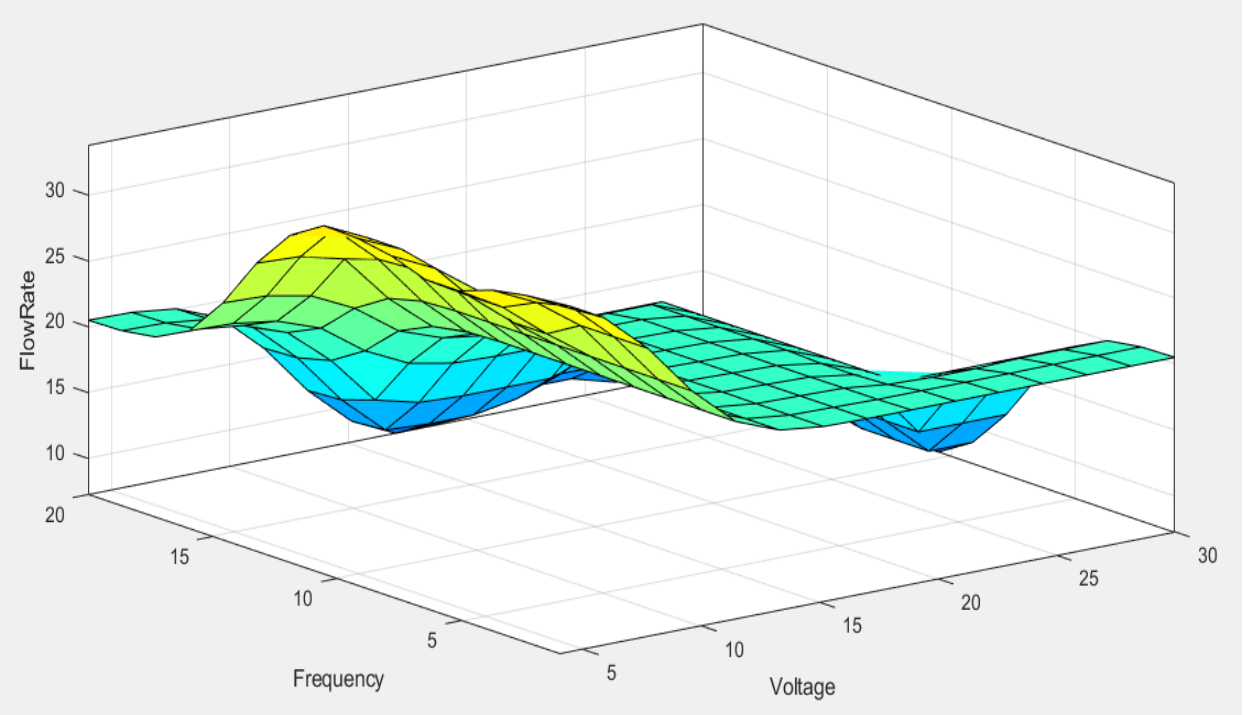

Fig. 8. 3D graph between the input voltage and frequency applied to the micropump with respect to the output flow rate.

Fig. 7 and 8 show that the back pressure will be high as the applied input voltage and frequency will low, and back pressure will be low as the applied input voltage and frequency will high.

Results and Discussion

The MATLAB Rule viewer displays the rules defined in the rule editor. The corresponding output crisp value of flow rate and back pressure for any two crisp values of the input variables voltage and frequency can be viewed in the rule viewer as illustrated in Fig. 9.

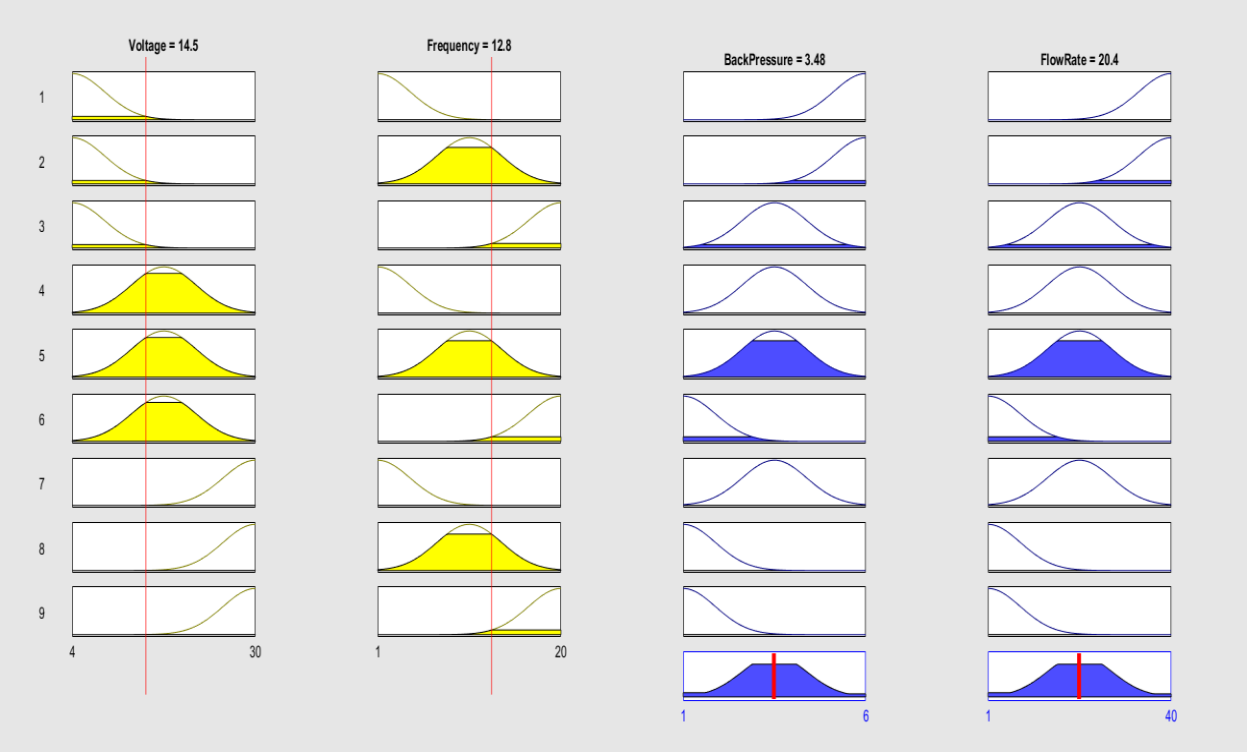

Fig. 9. Rule viewer to show up two outputs for the corresponding two inputs

For the calculations of the results, the input crisp values are selected, and their corresponding output crisp values are noted. The selected input crisp values for voltage are 14.5V and frequency 12.8 Hz and the corresponding output crisp values for back pressure are 3.48 KPa and flow rate 20.4 ul/min as shown in Fig. 9. These values of membership functions are calculated as:

$$A1= 30-14.5/30=0.5166 \text{ V}$$

$$A2= 1-A1= 0.4833 \text{ V}$$

$$A3= 20-12.8/20=0.36 \text{ Hz}$$

$$A4= 1-A3= 0.64 \text{ Hz}$$

For the corresponding membership function values A1, A2, A3 and A4, the following 4 rules out of total nine rules are selected. The Mamdani formula is used to calculate the minimum membership function value (Gi) and the Singleton value (Vi). The total of all minimal membership function values and singleton values is calculated, and by using these values the crisp value of output is derived as shown below:

For output 1

$$\sum Mi=0.999$$

$$\sum (Mi \times Si) = 0.03197$$

$$\text{Mamdani's model} = \sum Mi \; x \; Si \; / Mi^* \; 100 = 3.537$$

Error calculation

Absolute error = theoretical – simulated value

= (3.537 – 3.48/3.537) *100

= 1.61%

For output 2

$$\sum Mi=0.999$$

$$\sum (Mi \times Si) = 0.20714$$

$$\text{Mamdani's model} = [\sum Mi \; x \; Si \; / Mi] * 100 = 20.734$$

Error calculation

Absolute error = theoretical – simulated value

= (20.734 – 20.4/20.734) *100

= 1.61%

Table II: Comparison between simulated and calculated value and their percentage error

Output	Simulated Value	Calculated Value	Error
Back Pressure	3.48	3.537	1.61%
Voltage	20.4	20.734	1.61%

Table II shows the comparison between the simulated and calculated value and their percentage error. The Crisp value of the output 1 from rule viewer is 3.48 and calculated value of Mamdani model is 3.537. The error between the simulated value and the calculated value is 1.61%. The Crisp value of the output 2 from rule viewer is 20.4 and calculated value of Mamdani model is 20.734. The error between the simulated value and the calculated value is 1.61%.

Conclusion

MEMS-based micropumps have gained a significant importance due to its wide applications in biomedical sector as well as in industrial sector. In biomedical sector it is used for drug delivery within implantable systems. In industrial sector it is used during the manufacturing

processes for the delivery of small amount of glue. In this work MATLAB fuzzy logic controller is used for the parametric estimation of the MEMS-based thermopneumatic micro pump. The effect of voltage and frequency applied on micro pump were studied on the back pressure and flow rate. The increase in voltages and frequency were decreased the back pressure and fluid flow rate. Similarly with a decrease in voltages and frequency were increased the back pressure and fluid flow rate. The difference between the MAMDANI calculated value and the simulated value from the rule viewer are 1.61% for both the output of back pressure and flow rate.

Author's Contribution: G.M., Conceived the idea; S.A.A.S., G.M., designed the simulated work in Fuzzy Logic Controller, and M.A., F.A., did the acquisition of data; F.A., G.M., M.A., M.S., executed simulated work, F.A., did the data analysis; G.M., M.S., wrote the basic draft, S.A.A.S., did the language and grammatical edits or Critical revision.

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