International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

Industrial Furnace Temperature Measurement Using Convolutional Neural Network (CNN)

Soniya R. Shetty[1], Ramesh T. Patil[2]

[1]*Student,Dept. of ENTC Engineering, Rajarambapu Institute of Technology, Islampur, Dist. Sangli, ShivajiUniversity, Maharashtra, India 415414.*

[2]*Associate professor, Dept. of ENTC Engineering, Rajarambapu Institute of Technology, Islampur, Dist. Sangli, Shivaji University, Maharashtra, India 415414.*

Date of Submission: 26-07-2020 Date of Acceptance: 06-08-2020

ABSTRACT: Furnace used in industries is a closed container with high temperature and pressure. As the temperature of furnace is very high it is difficult to accurately monitor its working condition. In many industries thermocouples or infrared pyrometer are used for measuring temperature of furnace but this can be damaged or fall-in-service due to high temperature. Hence it is required to be replaced every time. This paper presents the proposed work developed for monitoring the temperature of furnace using Convolutional Neural Network (CNN). Firstly the images of melting iron are captured using High resolution camera for a particular time period from specified distance and angle. This captured image are pre-processed and then fed to CNN as input. With the help PyTorch library of CNN feature of captured images are extracted and temperature of furnace is estimated.

KEYWORDS: Convolutional Neural Network (CNN), PyTorch, Furnace, Temperature.

I. INTRODUCTION

Furnaces are used in industries to provide heat. Furnace is specially used in iron and steel industries for melting iron. The process of melting of iron in the furnace is done at very high temperature; typically the temperature is higher than 1000℃. Maintaining such a high temperature for melting of iron is important task in the industrial process, hence the temperature should be monitored accurately.

As furnace is closed container with high temperature and pressure, so it is very difficult to accurately measure its temperature. In many industries thermocouples or land pyrometers are used for measuring temperature but this can be damaged or fall-in-service. Thermocouple is one type of sensor which is used to measure temperature, but to measure the temperature we have to place thermocouple in the furnace. It is very difficult to place the thermocouple in the furnace as the temperature of furnace is very high. Temperature measure range of thermocouple is below 1300℃ and temperature of furnace is higher than 1300℃ so thermocouple can be used maximum for 2-3 times due to which it has to be replaced every time. The land pyrometers measure temperature at a specific location without making contact with the object. Temperature measurement of furnace is difficult task using land pyrometer and results are also not accurate. All this process should be done manually every time. It is also very difficult and also dangerous to manually place the sensor on furnace.

This paper specifies a system which is developed for monitoring temperature of furnace using convolutional neural network (CNN). CNN is most reliable and recently in demand in large – scale image recognition. Firstly the images of melting iron is captured and required feature is extracted from images using CNN and based on results obtained from CNN temperature of furnace is calculated.

II. LITERATURE ON RELATED WORK

Now-a-days there are multiple methods developed to detect temperature of burning coal or iron.

[1].Introduced an image based flame detection and combustion analysis system of a blast furnace. Firstly an optical detector system is used to capture raceway images and features of flames are extracted using Digital image processing unit. The non-linear partial Least-square colorimetry and Monte Carlo method are used to detect the temperature of blast furnace. Multiple images from different raceway were captured and processed. The results obtained were that the temperature distribution fluctuates a lot in raceway and there is lot of temperature non uniformity in multiple

raceways. This method does not give the accurate result. CNN is very convenient method which can be used to extract features of the burning iron or even the burning flame. To extract feature using CNN firstly it is necessary to set feature maps in Convolutional neural network.

[2].Introduces correlation layer and also designed correlation loss. As there is lot of correlation variation of feature maps in the last layer of convolution they proposed correlation layer and correlation loss based on MNIST and CIFAR-10 dataset. They designed two strategies for multi-task training first is supervision and second one is initialization. The result demonstrated from their experiments was that by using some suitable correlation loss function and strategies, correlation layer can help to optimize the weight distribution.

[3].Introduced a flexible, high performance Convolutional neural network for Image classification. The high-performance GPU-based CNN variants were developed. This application had greater flexibility, speed and state of art generalization capabilities. This network was applied on MNIST, NORB, and CIFAR10. The error rate of 0.35% for MNIST, 2.53% for NORB and 19.51% for CIFAR10 was obtained.

[4].Investigated effect of deep convolutional neural network for large scale image recognition. This depth of was beneficial for state of art performance and classification accuracy.

[5].Introduced deep convolutional neural network for ImageNet classification. CNN was trained on 1.2 million high resolution images in the ImageNet LSVRC-2010. Error rate of 37.5% and 17.0% was achieved.

[6].Proposed deep convolutional neural network architecture to achieve new state of art for classification and to improve accuracy and quality. The intuition of multi-scale processing and Hebbain principle was used.

[7].Proposed deep convolutional neural network for inverse problem in imaging. The algorithm used is regularized iterative algorithm. The model was tested on various biomedical inverse problems like MRI, CT and DT and the results of CNN were well-suited for inverse problem and the computation time requires is also less.

[8].Developed a CNN method to extract ship from high resolution optical remotely sensed images. Firstly possible location of ship is identified and then feature of ship are extracted by training CNN .the results obtained are robust and efficient.

[9].Used deep convolutional neural network for fingerprint image identification for crime detection. Images are collected from crime scene and these images are pre-processed then the data is tested and trained into CNN. The results obtained from CNN are accurate.

[10].Introduced a thermal image enhancement using convolutional neural network. The CNN was trained to map low resolution image into high resolution image. Quality of image and performance such as visual odometry, image registration and pedestrian detection was detected.

This paper presents temperature measurement of furnace using convolutional neural network. This system designed is very efficient, accurate and low cost for measuring temperature.

III. METHODOLOGY

1. SYSTEM ARCHITECTURE

This proposed system is used to measure temperature of industrial furnace using convolutional neural network (CNN). The proposed block diagram of system is shown in Fig. 1.

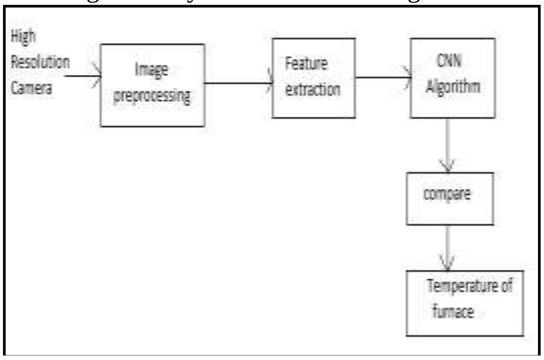


Fig. 1: Proposed block diagram

Here the images of melting iron are captured using high resolution camera. For better results and accuracy canon 7D camera is used in this system to capture image. Canon 7D is a semi-pro DSLR camera with 18.0MP and its maximum resolution and aspect ratio is 5184x3456 and 3:2 resp. As we have to detect the accurate temperature of melting iron so we have to monitor the full process of melting iron in furnace. Here for experimental purpose and to test the result the furnace which is having capacity to melt 1 ton of iron is considered. the This furnace takes complete one hour to melt 1 ton of iron, so we need to capture images of melting iron for complete one hour. The images are captured after particular time interval from start of process till the end of process of melting iron. The distance and angle of camera is fixed for entire process. Once the database of images is collected it is futher used pre-processing. Table I shows the specification of furnace used for experiment and testing purpose.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

Table I. Specification of The Furnace

Sr no.	Specification	Value
1	Capacity	1 ton
2	Temperature range	800-2000°C
3	Time requires	1 hour
4	Stability	± 0.1°C
5	Diameter	50cm
6	Depth	4 feet
7	Power	550 KW
8	Current	1597 A
9	CAP Volts	1517 V

2. PREPROCESSING

The images captured of melting iron are usually incomplete and contains noise. As the environment inside the furnace is very harsh we have chances of getting blur images, hence it becomes difficult to categorize the images and to maintain image details. Suitable enhancement method is required to pre-process these images for better results. These images are pre-processed using image processing algorithm like contrast image, change of colorspace from BGR to Gray, blurring image, image denoising, HSV image. With the help of this algorithm feature are extracted from the images. This pre-processing is done using OpenCv. These noise free and filtered images are then given as input to CNN for further processing

3. CNN (Convolutional Neural Network)

Convolutional neural network (CNN) has recently made a remarkable progress in object classification and image recognition [2]. Convolutional neural network consists of weighted neurons with bias applied to it. Each neuron receives several output and then process on it and produces an output. To extract the feature it has to be passed into number of layers. Each layer has relationship between the neurons in that layer. These neurons are trained properly to get desired output. The basic structure of convolutional neural network is shown in Fig. 2. There are two layers each consisting of convolutional layer and max polling layer and then fully connected layer.

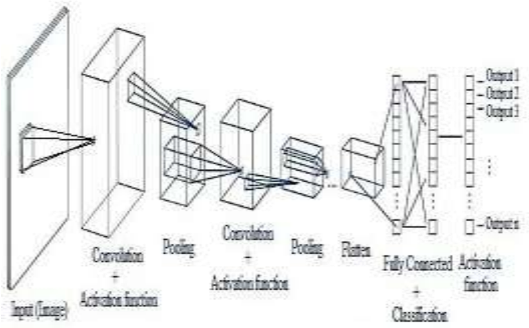


Fig. 2: Basic Structure of Convolutional Neural Network

3.1. CONVOLUTIONAL LAYER

Convolution layer is the first step in extracting feature from image. To perform the convolution operation convolution layer has several filters. This layer is characterized by kernel size, number of maps, connection table and skipping factor [3]. This network consists of 2 convolution layer with in channels=1, out channels=32, kernel size=5, stride=1, padding=2. Rectified Linear Unit (ReLu) is attached to each convolutional neural network for non-linear activation function. Number of output features is given as:

$$x_{out} = \left[\frac{x_{in} + 2p - k}{s}\right] + 1$$

Where,x_{out} indicates number of output featuresx_{in} is input features, p is padding size, k is kernel size, s is stride size.

3.2. MAX POOLING LAYER

The next layer is max pooling layer which performs down sampling operation due which the dimension of feature map gets reduced along each direction. And new pooling feature map is developed of reduced size. In this system 2 max pooling layers are used.

3.3. FULLY CONNECTED

The max pooled feature map obtained from max pooling layer is actually a 2-dimensional arrays. In the next step this 2-dimensional arrays are converted into a single dimensional. These arrays are flattened into continuous single 1D linear vector. For further classification of image this 1D matrix is given as input to fully connected layer.

4. TEMPERATURE MEASUREMENT

The exact feature is extracted from the image after passing through this entire layer. Firstly

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

the neurons are trained according to the intensity of pixels of image. Once the training is done on neurons this network is then used on images were according to the intensity of pixel in image the temperature is measured.

Table II. Measurement of temperature and error

Image no.	Actual temperature (℃)	Trained temperature (℃)	Error	Accuracy (%)
1	845	800	45	94.67
2	927	880	47	94.65
3	940	960	-20	97.87
4	1148	1088	60	94.77
5	1192	1120	56	95.30
6	1539	1400	139	90.96
7	1576	1520	56	96.44
8	1908	1860	48	97.48

Table III. Measurement of temperature of different material

Type of material	Actual temperature (℃)	Trained temperature (℃)	Error	Accuracy
Cast iron	1908	1860	48	97..48
Aluminium	1284	1348	64	95.01
Copper	1484	1541	57	96.16
lead	1084	1167	83	92.34

Table II shows the CNN predicted temperature value and actual temperature valve of furnace. Different types of material are used in furnace for melting process. Cast iron, aluminium, lead and copper are the material melted in furnace for production of different products. As the melting point and strength of each material is different hence the temperature of each material will also vary. Table III shows the melting temperature value of each material.

IV. IV. EXPERIMENTS

1. TRAINING PROCESS

The training process in network is done by using ResNet algorithm of convolutional neural network. The ResNet algorithm can train number of layers without vanishing gradient. For the training of images we need to build ResNet model which is easily done using source library of machine learning; it is used for application of deep learning. In PyTorch there are lot of pre-trained ResNet architecture available.

PyTorch is very reliable and easy to use library of machine learning to build ResNet architecture. PyTorch has torchvision.models which consists of large number of pre-trained ImageNet dataset and deep learning models. This torchvision.models contains many ResNet architectures, but for this system ResNet18 architecture is used to perform convolution operation on images. ResNet18 indicates that it contains 18 layer of convolution in its model. The neurons are trained using ResNet algorithm and the passed through layers of ResNet and temperature is estimated.

Generic mathematical model of residual blocks of ResNet is given by following expression. Data feature mapping is given as,

$A * u = f$ (1)

Where, f is image data and u is feature tensor such that $u \geq 0$.

To solve (1) feature extraction is considered as an iterative procedure.

$u^i = u^{i-1} + B^i * (f - A * u^{i-1}), i = 1:v.$ (2)

Considering the special activation function $\sigma(x) = \mathrm{ReLu}(x) := \max\{0, x],$

$$u^i = u^{i-1} + c \circ B^i * \sigma(f - A * u^{i-1}), \quad i = 1:v. \quad (3)$$

Introducing the residual

$$r^i = f - A * u^i \quad (4)$$

The iterative process in eqn 2 can be written as,

$$r^i = r^{i-1} - A * \sigma \circ B^i * \sigma(r^{i-1}), \quad i = 1:v \quad (5)$$

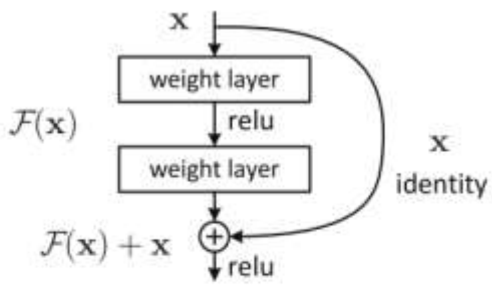


Fig. 3: Residual block

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

2. PERFORMANCE AND ACCURACY

The Convolutional neural networks ResNet architecture can build large number of convolutional layer with high performance. Due to ResNet algorithm drawback of previous architecture are eliminated like previously if number of layers increases the loss function is generated due to which performance of network is reduced.ResNet uses identity shortcut connections concept, in this concept the layers that are identical are skipped and activation function of previous layers are used for the process. Due to this concept the layers of network are reduced and performance is increased. As this ResNet models are built using PyTorch, hence results obtained are more accurate and contains minimum error. The graph of analysis of actual temperature and trained temperature is shown in fig 4.

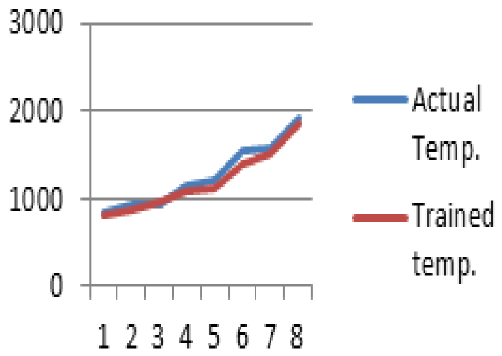
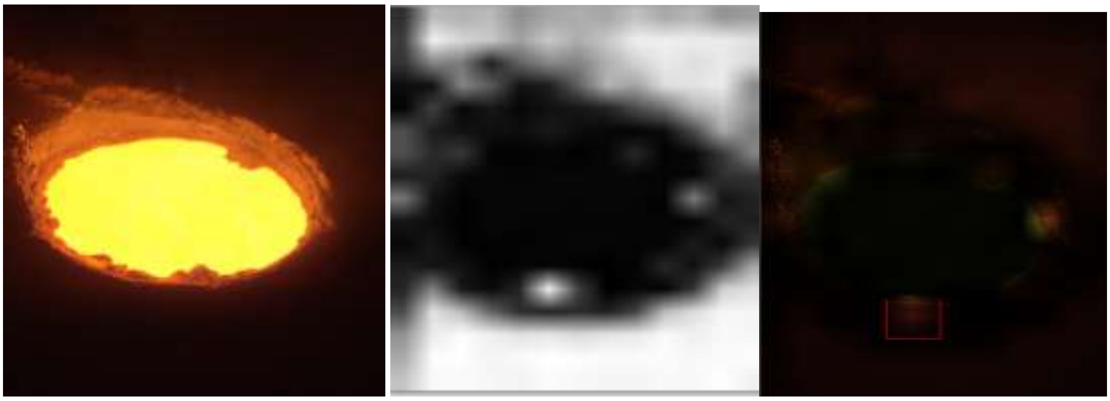


Fig. 4: Graph of actual temperature and trained temperature.



(a) (b) (c)

Fig. 5: (a) Original image (b) Image after Convolution (c) Warm area detected for measuring Temperature

V. RESULTS

This system predicts the temperature of melting iron in furnace. The result obtained is very close to actual temperature of furnace. Due to use of ResNet architecture we obtain more accurate and better results than previous architecture.

With the help of high resolution camera images of melting iron are captured for specified time interval. For experiment purpose and for testing results one of the image of melting iron of particular time is considered. Fig 5(a) shows the original image of melting iron in furnace. Camera is placed at the distance of 4 feet above the furnace. All the images from start of process till end of process are captured from this fixed distance and angle. This image is fed as input to convolutional neural network and feature is extracted from the original image.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

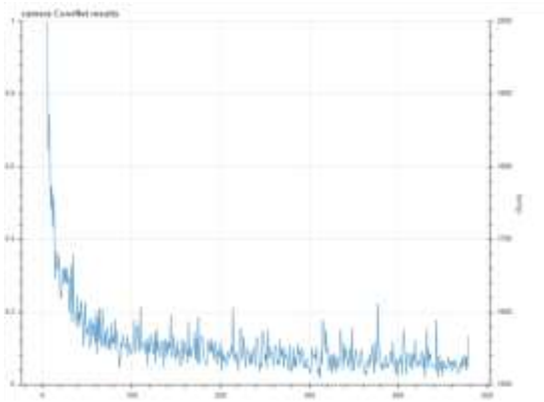


Fig. 6: Convolutional Neural Network results

The result of convolution operation is shown in Fig 5(b) and the network is trained in such a way that it detects all the warm area in the image for temperature measurement. Fig 5(c) shows the warm area detected for measuring temperature.

Fig 6 shows convolutional neural network results obtained from convolutional image. The graph in Fig 6 shows the temperature variation in all the area of image. Wherever there is warm area the temperature is high. The red rectangle indicated in Fig 5(c) shows the warm area which indicates high temperature. This temperature is the actual temperature of melting of iron at that point.

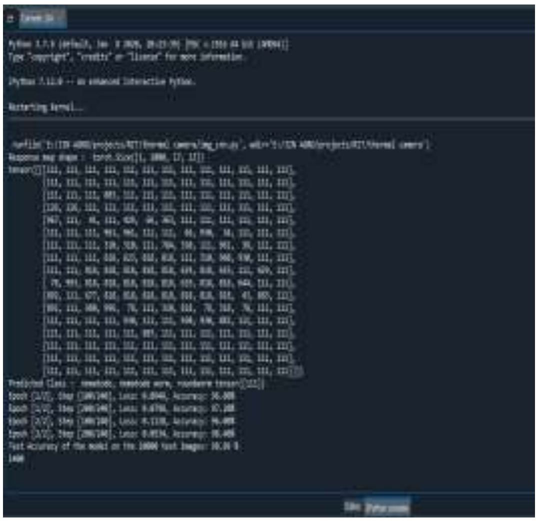


Fig. 7: Tensor values of output image with accuracy results

As we trained convolutional neural network to detect warm part in image then wherever there is warm area detected the tensor in PyTorch will give value 111 as shown in Fig 7. The accuracy and loss is also mentioned in fig 7.

VI. CONCLUSION

In this paper, we presented a system that measure temperature of furnace using convolutional neural network. Images of melting iron were captured using canon 7D camera for particular time interval from fixed distance and angle. The database of images at every time interval is collected and then pre-processed for better results. These pre-processed images are then fed to convolutional neural network for further processing. The neurons are trained in such a way that we get the temperature of melting iron from its images. The training of neurons is done by using ResNet algorithm which is very efficient algorithm of convolutional neural network. To build this ResNet model PyTorch Library is used. This is one of the most reliable libraries of machine learning. According to the colour intensity of the image of melting iron in furnace tensor values also changes, the area having high temperature is indicated by tensor value of 111. This value indicates the temperature of melting iron of furnace. This system is very advanced and flexible for temperature measurement of furnace.

REFERENCES

[1]. Ruixuan Zhang, Yuxin Cheng, Yan Li Dongdong Zhou, and Shusen Cheng, "Image-Based Flame Detection and Combustion Analysis for Blast Furnace Raceway," IEEE Transactions on Instrumentation and Measurement, April 2019, vol. 68, no. 4, pp. 1120-1131.

[2]. Jiahuan Zhou, Di Xiao, Mengyi Zhang, "Feature Correlation Loss in Convolutional Neural Networks for Image Classification," IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 2019, pp. 219-223.

[3]. Dan C. Cires, Ueli Meier, Jonathan Masci, Luca M. Gambardella, JurgenSchmidhuber, "Flexible High Performance Convolutional Neural Networks for Image Classification," Proceedings of the Twenty-Second International Joint Conference on Artificial Intelligence, 2019, pp. 1237-1242.

[4]. Karen Simonyan, Andrew Zisserman, "Very Deep Convolutional Networks for large-scale image recognition," Published as a conference paper at ICLR, 2015, pp. 1-14.

[5]. AlexKrizhevsky, IlyaSutskever, Geoffrey E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks,"

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 672-678 www.ijaem.net ISSN: 2395-5252

[6]. CristianSzegedy, Wei Liu, YangqingJia, Pierre Sermanet, Scott Reed, Dragomir Anguelov, Dumitru Erhan, Vincent Vanhoucke, Andrew Rabinovich, "Going Deeper with Convolutions." CVPR2015, pp. 1-9.
[7]. Kyong Hwan Jin, Michael T. McCann, Emmanuel Froustey, Michael Unser, "Deep Convolutional Neural Network for Inverse Problems in Imaging," IEEE Transactions on Image Processing, 2017, pp. 1-14.
[8]. Fuqiang Lei1, Wenliang Wang, Wei Zhang, "Ship Extraction using Post CNN from High Resolution Optical Remotely Sensed Images," IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 2019, pp. 253-2535.
[9]. Pavithra. R, K.V. Suresh, "Fingerprint Image Identification for Crime Detection," International Conference on Communication and Signal Processing, April 4-6, 2019, India, pp. 0797-0800.
[10]. Yukyung Choi, Namil Kim, SoonminHwan,In So kweon, "Thermal Image Enhancement using Convolutional Neural Network," IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2016, pp. 223-230.
[11]. Jiudong Yang, Jianping Li, "Application Of Deep Convolution Neural Network," 978-1-5386-1010-7/17/$31.0 IEEE, 2017, pp. 229-232.
[12]. Tianyi Liu, Shuangsang Fang, Yuehui Zhao, Peng Wang, Jun Zhang, "Implementation of Training Convolutional Neural Networks,"
[13]. AmitChakraborty ,"Image Processing and Image Pattern Recognition A Programming Tutorial," First International Conference on Artificial Intelligence for Industries, 2018, pp. 122-123.
[14]. Hoo-Chang Shin, Holger R. Roth, MingchenGao, Le Lu, ZiyueXu, Isabella Nogues, Jianhua Yao, Daniel Mollura, Ronald M. Summers "Deep Convolutional Neural Networks for Computer-Aided Detection: CNN Architectures, Dataset Characteristics and Transfer Learning," DOI 10.1109/TMI.2016.2528162, IEEE, 2016, pp. 1-14.
[15]. TreesukonTreebupachatsakul,Poomrittigul, Suvit,"Bacteria Classification using Image Processing and Deep learning,"

International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 02 Issue: 01 DOI: 10.35629/5252

www.ijaem.net

Email id: ijaem.paper@gmail.com