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Editorial Preface

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Neural Network Based Classification and Diagnosis of Brain Hemorrhages

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Abstract

The classification and diagnosis of brain hemorrhages has work out into a great importance diligence in early detection of hemorrhages which reduce the death rates. The purpose of this research was to detect brain hemorrhages and classify them and provide the patient with correct diagnosis. A possible solution to this social problem is to utilize predictive techniques such as sparse component analysis, artificial neural networks to develop a method for detection and classification. In this study we considered a perceptron based feed forward neural network for early detection of hemorrhages. This paper attempts to spot on consider and talk about Computer Aided Diagnosis (CAD) that chiefly necessitated in clinical diagnosis without human act. This paper introduces a Region Severance Algorithm (RSA) for detection and location of hemorrhages and an algorithm for finding threshold band. In this paper different data sets (CT images) are taken from various machines and the results obtained by applying our algorithm and those results were compared with domain expert. Further researches were challenged to originate different models in study of hemorrhages caused by hyper tension or by existing tumor in the brain.

Keywords: Brain hemorrhages, CAD system, Region Severance Algorithm.

1. INTRODUCTION

Image processing and analysis is a prevalently used technological tool for the medical investigations and their diagnostics. Image processing[1] and followed by its scrutiny is a very important step in developing tools as medical probes and diagnostics. In summary, image processing process comprises of important set of sequential phases that entail the regime of medical diagnostics. As such, it leads to improve the accuracy of the diagnosis and accurate fixation configuration for surgical operations. Medical diagnosis is one of the most important areas [2] in which image processing procedures are fruitfully applied.

Brain Hemorrhage is a condition caused due to a sudden stroke to a person after blood leaks out from the blood vessels in the brain. This situation occurs due to the breakage in the wall of blood vessel. The blood spills out of the blood vessel and enters the area, where vital tissues and cells of brain reside. Blood spills over Brain tissues those tissues and cells; this in turn causes the patient to become seriously ill and needs immediate medication/treatment. There are mainly four types of Brain Hemorrhages. They are Epi-dural Hemorrhages (EDH), Sub-dural Hemorrhages (SDH), Intra-cerebral Hemorrhages (ICH), and Intra-ventricular Hemorrhages (IVH). Epi-dural Hemorrhage, involves bleeding between the skull and the Dura matter, and it is most commonly related to traffic accidents, and much frequently encountered than SDH. A subdural hemorrhage(SDH) is caused [3] by bleeding, that takes place due to the rupture of one or more of the blood vessels (typically veins) that travel in the subdural space, located between the surface of the brain and the a thin layer of tissue that separates the brain from the skull. The main cause of Intracerebral Hemorrhage is Hypertension.

Computed Tomography (CT) is a non invasive technique to give [5] CT images of each part of the human being body. CT scans use the radiation as X-rays which is detected by a series of sensors that feed [4] information into a powerful computer. Because of the sensitivity of the sensors and the computer reconstruction, a CT scan can show the actual structure of the brain, blood vessels, and other tissues within skull. CT is the most preferable imaging system since it can work over unconscious patients in the emergency room [6]. Because of the unstable vital signs, Magnetic resonance imaging (MRI) is not possible in majority of unconscious patients.

The CT scan of a brain image contains little information which requires more computations in retrieving the region of interest. CT images are digital images, in which each pixel is expressed by its corresponding gray value. The background region of a CT Brain image has a very low gray value, for X-ray hasn't been absorbed in this part. Thus, the boundary of object can be identified [7] in CT brain images usually based on the change of gray value. Images collected from multiple configurations (angles) are posed to systematic analysis. Information from these images is used to detect the abnormalities. Detection and diagnosis of Brain Hemorrhages is one of the emerging fields of technologies in the row of efficient strategies through which a classified computer based system is designed.

A detection system which is anticipated to be effective in increasing patients life span used over a large number of patients who would be likely to have hemorrhage (ie., approximately one lakh patients suffer from hemorrhages annually and two- third of them are successfully diagnosed and the rest one third are not diagnosed) would be of significant influence in the field of Medical Diagnostic Automated. The procedure that is usually adopted over the globe for the analysis of images is bound to involve high risk of biased variants, which independently depend on the experience and skill of the Domain Expert. A Domain Expert (e.g., a medical practitioner) is one who is having widespread, accessible knowledge that is pre-arranged for its utility in practice, and is turned to the certain particular problems in hand. For example, at the time of solving regular cases, the specialist physician known as Expert physician makes use [8] of instant non-analytic responses. Non-analytic reasoning refers to a specific procedure, where one considers as whole (such as a medical case), rather than thinking about each characteristic of problem. As diagnostic errors are common in daily clinical practice, some of the errors can mislead the Domain Experts, which result in false-planning of treatment. This indirectly can affect the patient's survival.

Diagnostic errors account for a substantial portion of all medical errors, and strategy for their avoidance [9] have been explored. Hence, an effort is needed to minimize this kind of errors and prevent them. To ease out the Domain Experts to for their arriving at a more objective oriented decision regarding diagnosis, efforts are a foot to develop [10] computer-based systems. The objective of this research is to develop a CAD system that identifies Different types of Hemorrhages and classify them to help in the management of patients suffering from head injury or acute neurological disturbance in an emergency. In emergent conditions, expert radiologists may not be readily available to provide the required crucial image interpretation. Therefore, it is the duty of the clinicians to interpret the information from the images. If the clinician is not best suited for the task, then false treatment planning may take place. It is therefore believed that CAD may become useful in these situations.

2. METHODOLOGY

2.1. CAD system

The CAD system is much helpful for diagnosis and treatment. It is important to reduce [11] the expert's workload. With the use of CAD system by radiologist's for digital medical imaging, the demand for well-organized medical imaging data storage and retrieval techniques has increased [12]. Data tests and clinical practices exhibit [11] that the database is very useful for this Computer-aided diagnosis system (CAD) system. The typical structural design of a CAD system comprises four main modules for image pre-processing, description of regions of interest (ROI), mining and selection [13] of features and classification of the preferred ROI.
With the introduction of computer-aided diagnosis system (CAD) the work load of radiologists has been drastically reduced. The conventional approach is to partition an image into a set of regions and to distinguish the image by a combination of the attributes of its regions. [11], with the use of Computer-aided diagnosis system (CAD) by radiologists for digital medical imaging, the demand for well-organized medical Imaging data storage and retrieval [12] techniques has improved.

2.2 Procedure

The present computer based Brain Hemorrhage Diagnostic Tool is built upon a fundamental aspect of 'Automation' in medical diagnostic activity research. A possible consensus reached between the medical diagnostic experts researchers working in the fields of medical diagnosis and the computer professionals, the drive is bound to evolve an automated, time saving economical method of hemorrhage diagnosis , which is free from any risk, further, the process represents a non-invasive diagnostic tool for the detection of brain Hemorrhage. During the processing of automation of CT scan, several procedures are adopted on the essential image, viz., the skull removal, gray matter removal, horns detection, hemorrhage detection etc. Images, the whole gamut of heuristic divisions are divided such that hemorrhage can be easily determined whether hemorrhage occurred and if so, how to locate it. This feature of localization of hemorrhage consists one of the important features which are given as input component of information to the 'perception' process.
An overview of the proposed PC based automated Brain Hemorrhage Diagnostic method presented in block diagram shown in figure 1 gives how the classification of image can be done. According to the figure 1 a set of images are taken and in that vital and outmoded are separated. The vital images are considered and location and shape of hemorrhage is identified, with the shape of hemorrhage we define the type of hemorrhages which was discussed in third phase. The entire Methodology is divided into three phases.

2.2.1 Phase1: Fixing the number of required images

The first phase is image processing which directs to abstract characteristics from the normal or atypical structure. The intention of pre-processing is to mend the eminence of the information through the application of methods which can suppress the noise, and modulate the edges of image structures and distinction. Detection and diagnosis of Brain Hemorrhages, is one of the emerging fields of technologies involving complex strategies through which a classified computer based system is designed. Images collected from multiple configurations are passed to systematic analysis. Information from these images is used to detect the abnormalities.

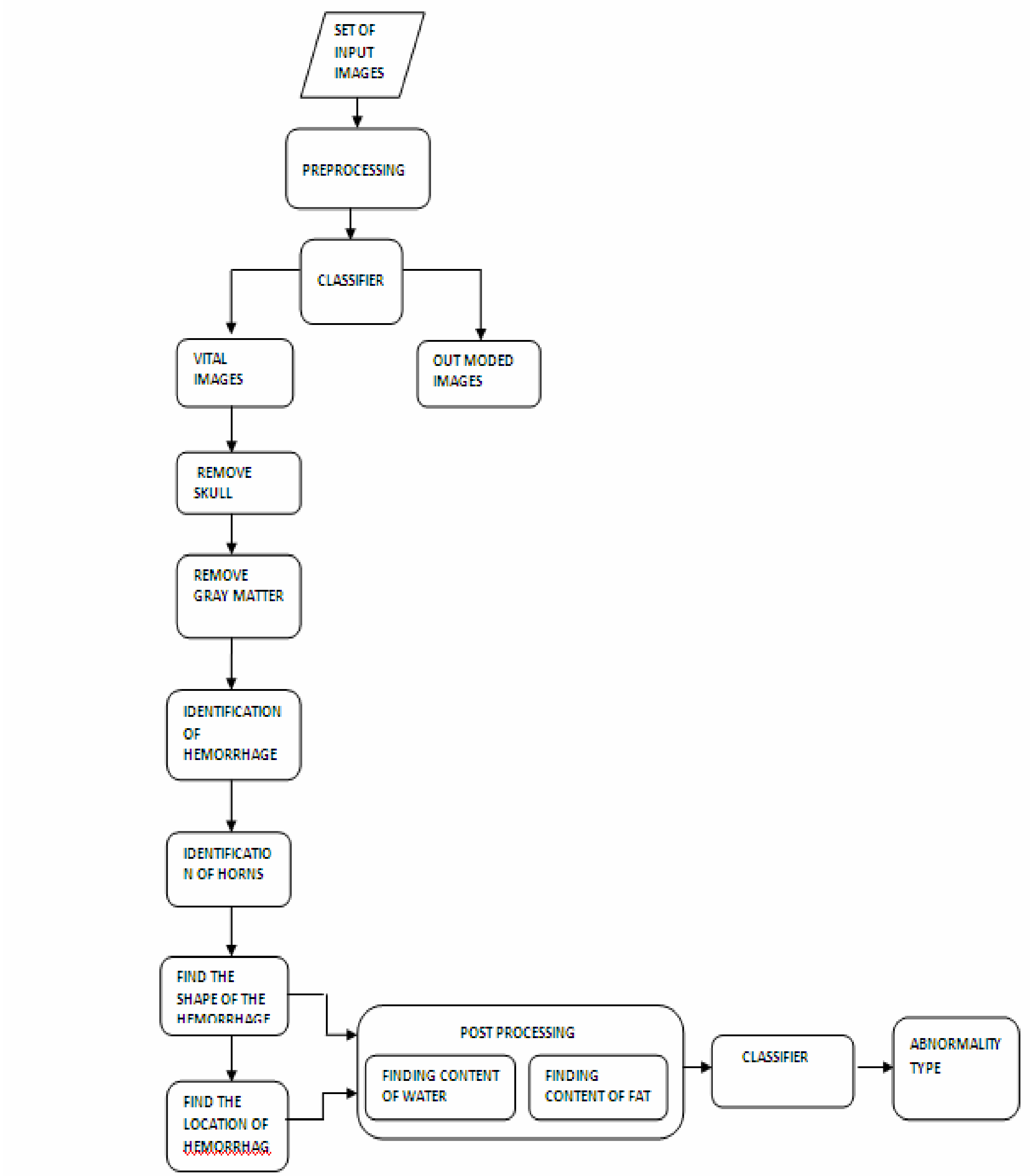


Figure1. Block diagram showing to classify the images.

2.2.2 Phase2: Abnormality Identification

The second phase is the excavation of the medical images characteristics, in other terms; the step is also the functioning of the quantization of image characteristics. The objective of this step is to quantize the characteristics that have snatched by computer in the first step. Once the features have been drawn out, selection of a split of the toughest feature is crucial, directing at improving classification precision and reducing the whole complexity. The analysis of the indication, such as the volume, compactness or shape of the pathological alters regions, is the most value demonstration in iconography for the doctor conclusions that they have made.

A region severance algorithm is introduced here to detect and locate the hemorrhage.

Region Severance Algorithm (RSA):

Let $X[m,n]$ be input image matrix of m $\times$ n size.

Let $Y[p,q]$ be an estimated image matrix of p $\times$ q dimensions

Assuming that $m = p, n = q$

$Y[i,j] = X[i,j]$ for all $(i,j) > T$

Where T is the threshold value and
i ranges from 1 to m and
j ranges from 1 to n

Source images usually have multi-modal [14] distributions, which are difficult to model for diagnosis. However, the consistency of the estimator, $Y[p,q]$ can be obtained using threshold value T as

$$Z[i,j] = X[i,j] - Y[i,j]$$

Upon repeated (iterative) application of the above steps, unwanted Regions can be eliminated from the resultant image Z. Apply the techniques like Filtering and masking helps to remove Noise from the image. Infact unwanted noise, which can cause difficulty in processing.

Noise over Image will be eliminated [15] by applying any one of the various filtering techniques such as Median filtering, Order-Statistic Filter, Mode Filtering. After applying these techniques the resultant image reveals the existence of abnormalities. The features which are required for classify the hemorrhage can be extracted.

The main goal of this phase is to identify the hemorrhage which is present in the encephalic region. Region Severance Algorithm (RSA) is applied on the images which are obtained from the first phase of the automation process. In this phase, the threshold band is taken as a parameter for the detection of hemorrhage.

Application of Region Severance Algorithm on Brain CT image:

The CT image consists of regions like skull, gray matter, white matter and abnormal regions like blood clots, accumulated solvents, fats etc. But our main focused is on encephalic region which lies inside the skull. In order to get the encephalic region, skull portion should be excluded [16]. Therefore, our first step is to isolate Skull region from encephalic region in the image.

Elimination of skull region from the image:

The skull is in white color, whose threshold is of maximum in a gray scale map. Hence, we simply treat those pixels with maximum intensity as the skull. The interior region refers to the brain content inside the skull. The process of boundary detection is carried out to eliminate the skull region.

Consequently, that the Boundary contains points with maximum intensity, which belongs to the skull. Note that there are two other regions that are also in white color. These two regions belong to the hard machine surfaces of CT scan device.

Remove grey matter:

Most of the content inside the skull is gray matter [17]. The hemorrhage part of grey matter should be separated. The resultant image contains horns and the hemorrhage part. If the pixel intensity lies between grey level threshold values, then it is considered as the pixel which is present in grey matter. We extract all those pixels whose grey level falls in that range.

Detection of Hemorrhage:
From the intermediate image, which is obtained from the previous step, hemorrhage can be detected. A Specific threshold is taken for the hemorrhage region. If the pixel intensity in the image lies between the identified gray level threshold bands, then it is considered as the pixel which belongs to hemorrhage region. We extract all the pixels which are present in that range and group them, which form the hemorrhage region.Therefore, upon the application of Region Severance Algorithm on CT image, a group of images which pertain to the abnormal region (as the hemorrhage affected part) is accessed.

Detecting Horns:
In order to find the location of hemorrhage, identification of horns is important. Therefore there is a great need for the detection of horns. Specific threshold band is considered for the design of horn pixel. If the pixel intensity in the image lies between these grey level threshold bands, then it is considered as the pixel which belongs to the horns. We extract all the pixels which are present in that range and place the pixels in to the intermediate image.

Location of the hemorrhage:
The image which is obtained after the application of Region Severance Algorithm is divided into four equal parts. The relative density of the hemorrhage region in each part is compare with the other parts of the hemorrhage region. The part with maximum relative density value specifies the exact location of the hemorrhage.

2.2.3 Algorithm to find the Threshold band

A sample of ‘n’ images is taken from each machine.(‘n’ varies in the case of finding the band for Hemorrhage, water content, fat content).In our case,

n= 15 for finding the water content,
n=6 for finding the fat content.
n= ~40 for finding the Hemorrhage Threshold,

1. The desired region is separated manually using MATLABROI.

2. Hemorrhage region is subtracted from the separated image. To subtract the hemorrhage region, we change the hemorrhage pixels to zero.
   (This step is carried out only in the case of finding the threshold band for water and fat contents around the hemorrhage but not strictly for finding the threshold range for hemorrhage region).

3. For the resultant image, minimum and maximum values of the pixel intensity in the image are found. Let the values be $\mathbf{Z_{min}}$ and $\mathbf{Z_{max}}$.

4. These values are tabulated in a separate table.

5. Mean value for $\mathbf{Z_{min}}$ and $\mathbf{Z_{max}}$ is found which is treated as threshold range.

$$\mathbf{Zf_{min} = (\sum Z_{min})/n}$$
$$\mathbf{Zf_{max} = (\sum_{Zmax})/n}$$

Where ‘n’ is the number of samples.
Therefore,
Threshold band = $\mathbf{(Zf_{min}, Zf_{max})}$;
Using this Threshold band we extract the desired region.

The same procedure is applied for finding the Threshold band for Hemorrhage, water content and fat content.

Find water content and fat content around hemorrhage:
Water and fat contents are separated using Threshold band which is taken from the table. It is known that Water and fat content is present around the hemorrhage. Water region can be taken as the region which is dark in color around the hemorrhage and the fat region is the region which is very dark in color. To procedure to extract water and fat content is given in the above algorithm. Therefore the resultant images are the images which are left with water and fat content.

Shape of the Hemorrhage affected region:
A hierarchy of steps involved to determine the shape of the hemorrhage.

1) Reading the Input Image.

2) Converting the image to grayscale (if necessary). Input image can be an RGB image also. If the image is RGB image, it has to be converted to gray scale for performing necessary operations.

3) Edge detection techniques are applied on the image which is finally converted to Gray scale. Commonly used edge detection techniques are Canny Edge Detection, Sobel Edge Detection and Prewitt Edge Detection etc. The output of this method is a binary image, which is a matrix constituted elements of Boolean values. If a pixel value is 1 it signifies an edge. The most general method used is the Canny Edge Detection. The Canny method uses two thresholds to detect strong and weak edges. It includes the weak edges in the output, only if they are connected to strong edges. As a result, the method is more robust to noise predominantly it is likely to detect true weak edges.

4) The Connected components from a binary image that have fewer than N pixels are removed to produce another binary image N, which can be any integral value (for our method N=30).

5) Further, the background of the image is filled with holes as per the necessity. A hole is a set of background pixels that cannot be reached by filling in the background from the edge of the image.

6) Labeling is carried over the connected components in the Binary image. The output of this step produces a matrix, which is of same size as input Binary Image. But it contains the labels for the connected objects in Input Image. Several automated operations can be done on the output of the image.

7) Several properties of regions such as Volume, Centroid, Area, Convex Area, and Eccentricity etc. are measured for finding the shape of the hemorrhage. The information regarding the properties we need properties like cancroids, Area, Perimeter would be useful.

8) The Total size of the cancroids and the boundaries of the pertinent regions are calculated.

9) The minimum and maximum values are evaluated using the following formula.

$$form\{k\}(1,i) = \sqrt{((b(i,2) - cen(k).Centroid(1)^2 + (b(i,1) - cen(k).Centroid(2))^2}$$

10) The required value is estimated from the formula given by.

$$\text{conc}= {(area\_new)}/{(\max\_val * \min\_val * pi)}$$

11) If the value obtained in the previous step lies between 1.05 and 0.95 then we consider that the shape is convex. If the value obtained in the previous step lies between 0.5 and 0.25 then we consider that shape is convex.

2.3.4 Phase3 Classification of brain hemorrhages

The final step in the diagnosis process is to classify the hemorrhage with the help of a neural network, whose inputs are location and shape. The values of the inputs to the neural network are obtained from the above steps.

.

If the shape of the hemorrhage is concave and the location of the hemorrhage is near to skull (Fronto parietal region or perieto occipital region) then the hemorrhage is Sub-Dural hemorrhage.

If the shape of the hemorrhage is convex or bi-convex and the location of the hemorrhage is near to skull (parietal region) then the hemorrhage is Epi-Dural hemorrhage.

If the shape of the hemorrhage is irregular and the location of the hemorrhage is on the ventricles then the hemorrhage is Intra-Ventricular hemorrhage

.

If the shape of the hemorrhage is homogeneous (not mandatory) and the location of the hemorrhage is in parietal region or in occipital region or temporal or frontal region then the hemorrhage is Intra-Cranial hemorrhage.

If the shape of the hemorrhage is concave and the hemorrhage is present in the frontal and parietal regions then the hemorrhage is Sub-Arachanoid hemorrhage.

We take pixel intensity as the main supporting evidence for the diagnosis process. As image is represented by matrix consisting different values which represent pixel intensities. Therefore, considering pixel intensity as the main supporting evidence generates exact results.

It is known that CT was slightly better for showing [18] hemorrhagic components; documenting 77% of hemorrhages compared with 71% for MR. The appearance of the contusions on MR were variable, depending on the T1- and T2-weighting of the images and the constituents of the contusions, such as edema, hemorrhage, and encephalemalacia. CT is very effective for evaluating acute head trauma, but MR is recommended for documenting brain contusions during the sub acute and chronic stages of head injuries.

CT has remained the primary imaging method in acute head trauma because of its sensitivity in detecting acute intracranial hemorrhage and its rapid scanning capability. MR has not made much impact in this area primarily for three reasons: first, acute hemorrhage may be iso intense and difficult to see on the MR images; second, these patients require various support equipment, much of which cannot be taken into the magnet room; and third, MR imaging requires more time, and time is a critical factor in patients with intracranial hemorrhage. CT overcomes all these problems over MRI Therefore CT are used extensively.

Domain-Expert Diagnosis:

Normal Brain: (Inferences obtained from the slices starting from the base skull to hyperital cortex).

I. The Size, Shape and position of the ventricular system are within normal limit.
II. Sulsi, Sylvian fissures and basal systems are normal.
III. Subarachnoid areas are normal.
IV. No evidence of midline shift.
V. No-evidence of intracranial-extra cranial fluid collections.(Collections can be blood or anything).
VI. Cellar and Para-cellar regions are normal.
VII. Bony structures shows normal.

VIII. No Evidence of Bony injury.

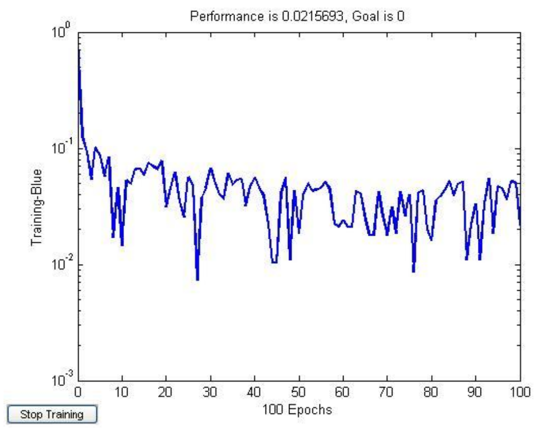
For Hemorrhagic CT image:

I. Examination of midline shift in CT image.
II. Examination of Sulsi, Sylvian fissures, basal systems.
III. Examination for the fractures in the bony window.
IV. Examination of subarachnoid areas.

RESULTS AND DISCUSSIONS

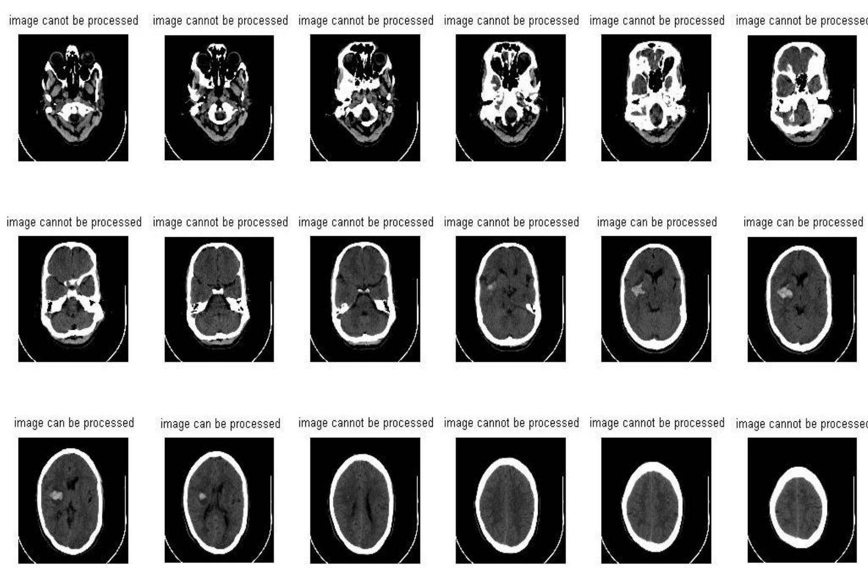
All the outputs which are generated are for the images which are taken for SIEMENS -SPEED PRO MACHINE.

Figure 2: Training graph



Above figure shows a training graph shows the resultant graph drawn out of the training process of the perceptron. It is noticed that graph is drawn for 100 epochs and the performance is 0.0215

Figure 3: Essential and Non Essential Images.



The above figure shows that the classifier has successfully separated the images into two separate groups' namely 'VITAL' and 'OUTMODED' images.

Phase 2:
In the second phase, the VITAL images are exported for further analysis. Since, the CT image consists of regions like skull, gray matter, white matter, abnormal region like blood clots, hemorrhages etc. From these regions, unwanted regions like skull region, gray matter region should be separated since our region of interest is Hemorrhage region.

Figure 4: Patient image

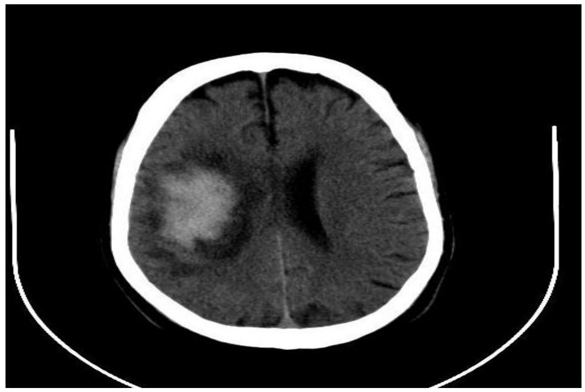
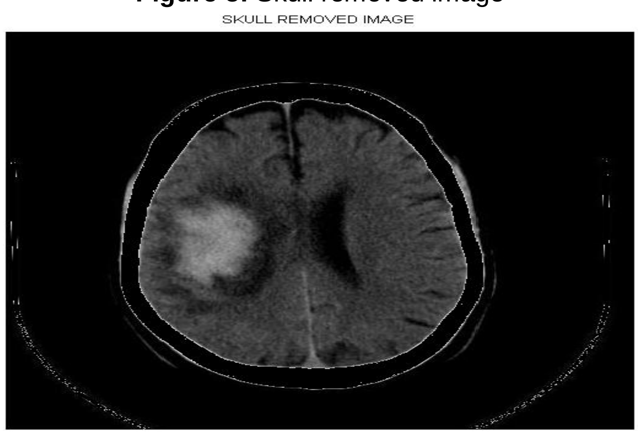


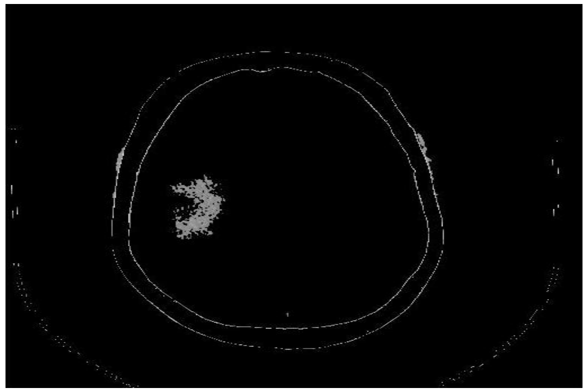
Figure: 4.shows the input image which contain regions like skull, gray matter, abnormal regions like hemorrhage.

Figure 5: Skull removed image



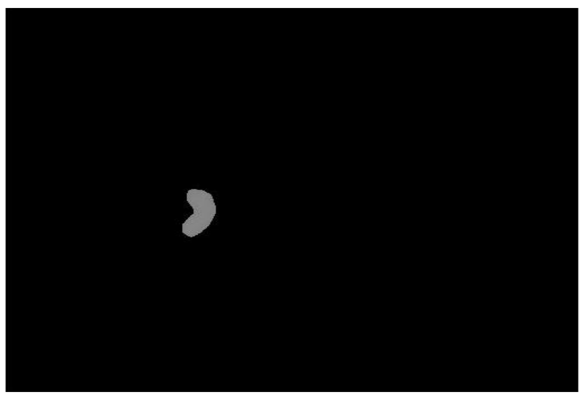
The above figure shows the resultant image which is obtained after the execution of first step in second phase which is skull removing process.

Figure 6: Grey matter removed image



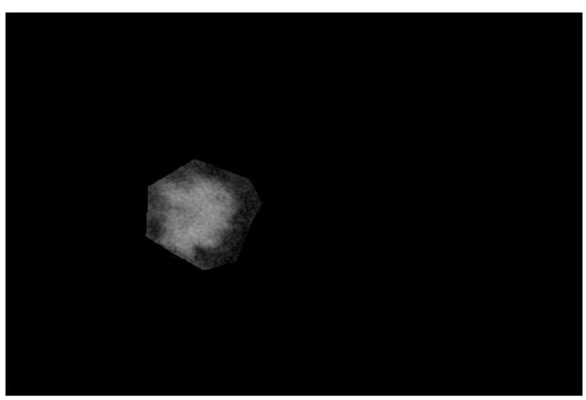
The above window shows the resultant window after removal of gray matter.

Figure 8: Hemorrhage image



As, the obtained grey matter removed image contains unwanted substances like noise which can cause difficulties in processing of hemorrhage detection. These substances are eliminated from the image by applying filtering and masking techniques.
In the process of separation some amount of information is lost. The loss of information does not have any impact in detection process.

Figure 9: Water with Hemorrhage region image



The above figure shows water image. Note that the hemorrhage is surrounded by water which is shown in black color. This region has to be extracted.

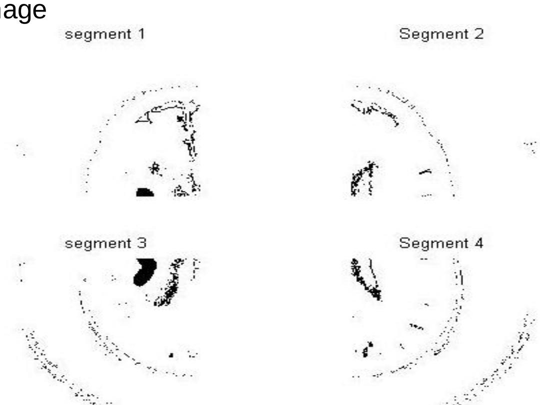
Figure 10: Water image

The above figure shows the water region which is extracted from the image which is obtained from the previous step. Note that this is the region which is around hemorrhage region.

Figure 11: Hemorrhage with horns

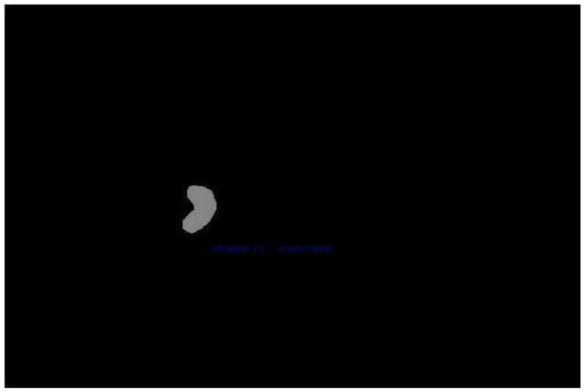
The above figure shows the location of the horns along with hemorrhage. Hemorrhage can be located at any one of the lobes [areas] Frontal Lobe, Occipital Lobe, parietal lobe, Temporal Lobe. Detection of horns is mandatory for finding the Location of hemorrhage.

Figure 12: segmented image



The above figure shows division of image into four equal parts which is useful for finding the location of hemorrhage. Please note that horns are located in each and every part.

Figure 13: Shape of hemorrhage



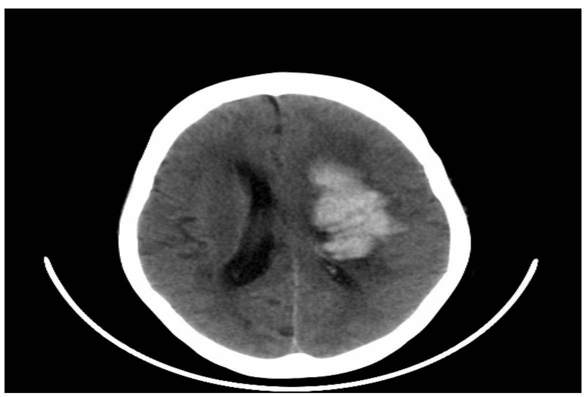
The above figure shows that shape of the hemorrhage and clearly displays that shape is concave.

Phase 3:

Finally, based on location and shape, hemorrhage is classified into different type with the help of Artificial Neural Network.

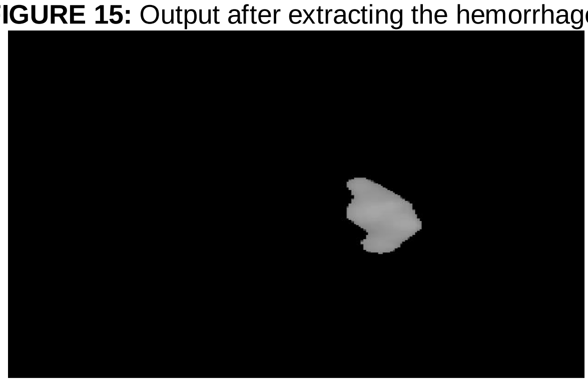
OUTPUTS FOR IVH:

Figure 14: IVH IMAGE



The above figure shows the input image which is representing Intra Ventricular Hemorrhage

FIGURE 15: Output after extracting the hemorrhage.



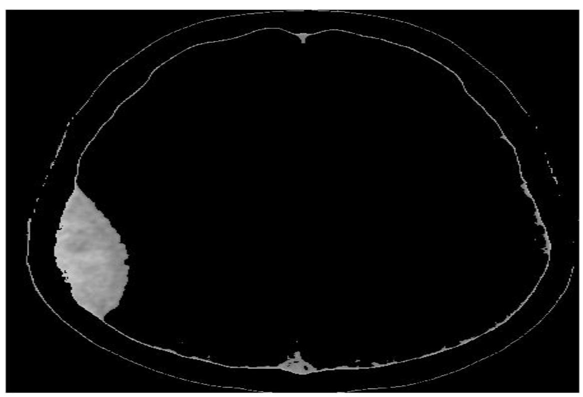
The above figure shows the output after extracting the hemorrhage.

OUTPUT FOR EDH:

Figure 16: EDH IMAGE

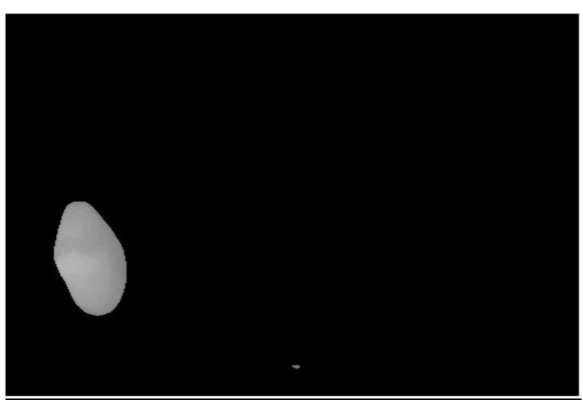
The above figure shows the input image which is representing Epi-Dural Hemorrhage

Figure 17: After removing skull and gray matter.



The above figure shows the skull removed image for Epi-Dural Hemorrhage.

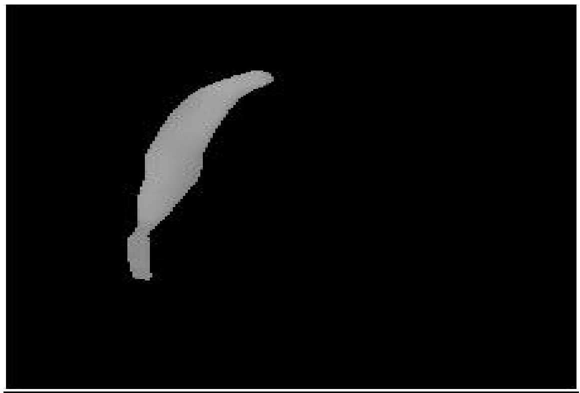
FIGURE 18: Output after extracting the hemorrhage



The above figure shows the output after extracting the hemorrhage.

OUTPUTS FOR SDH:

Figure 20: Output after extracting the hemorrhage



The above figure shows the output after extracting the hemorrhage.
Discussion of Phase 1:

Table 1: Table showing white matter count for different images

Image number	White matter count
1	44667
2	47538
3	52925
4	60795
5	60546
6	66192
7	70389
8	56205
9	55296
10	56169
11	57144
12	59613
13	62460
14	64041

The above table 1 shows the values of white matter which is present in the images .This is taken as the parameter for classification of images into VITAL and OUTMODED images. Note that the minimum value and the maximum value is 44667-70389.This can be treated as Threshold range.

Table 2: Table for evaluating white matter threshold band for different ranges

Observed Threshold band		Extracted threshold value		Extracted images
		Min	Max	
1000	5000	-	-	-
5000	10000	-	-	-
10000	20000	-	-	-
20000	40000	-	-	-
40000	50000	44667	-	-
43500	70500	44667	70443	90
44000	71000	44667	70443	90
44500	71500	44667	71244	92
45000	72000	44667	70443	90
45500	72500	44667	44667	90

The above table 2 shows the exact number of images that are present in the specific range. The minimum and maximum values of the white matter which are present in the taken specific range are also displayed. This table is used for obtaining the exact Threshold band for the white matter.

DISCUSSION OF PHASE 2

Table 4: Patient wise details which are classified by domain experts:

Patient Number	Total number of Images	Vital Images	Out Moded Images
1	17	9	8
2	19	13	5
3	20	9	11
4	14	10	4
5	18	11	7
6	24	13	11
7	18	12	6
8	13	8	5
9	11	8	3
10	18	11	7
11	19	11	8
12	18	11	7
13	13	8	5
14	13	4	9
15	14	9	5
16	22	10	12
17	21	9	11
18	22	12	10
19	12	4	8
20	21	9	11

The above table 4 shows the number of vital images and outmoded images of each patient of a single machine.

Table 5: Table for validating threshold band water content

Image number	Minimum Value	Maximum Value	Average threshold value
1	8	49	29
3	16	55	36
5	1	37	19
6	2	50	26
7	15	91	53
17	7	73	40
18	1	71	36
33	17	44	31
47	8	57	33
48	1	75	38

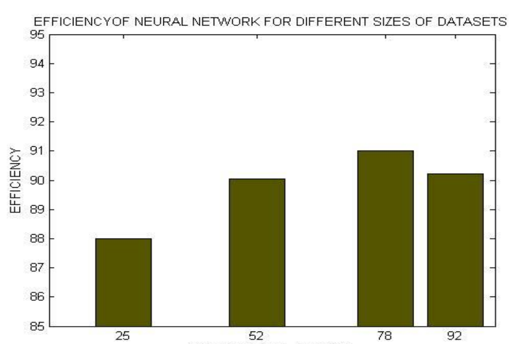
The above table 5 shows the minimum and maximum values of water content around hemorrhage for different patients. Average threshold is calculated from both minimum and maximum values. The lowest value and highest value gives the threshold band for hemorrhage which is 19 to 40 in our case.

Table 6: Efficiency calculation

Training data set size	Classification by our classifier		Efficiency (In %)
	Vital	Outmoded	
25	22	3	88.00
52	47	4	90.03
78	71	6	91.02
92	83	9	90.22

The above table shows that a total of a specific set of images of different sizes such as 25, 52, 78, 92 are taken as training dataset size. For each training data set size, values of fields such as VITAL, OUTMODED images are found and tabulated. The table also shows the values of efficiency which is calculated from the number of VITAL Images and the number of domain expert identified images which are suggested by the domain expert.

Figure 21: Efficiency of neural network for different data set sizes



The above graph shows the values of efficiency which is calculated from the number of extracted images and the number of domain expert identified images (which are suggested by the domain experts).From the graph, in a set of 25 images the network is 90% efficient.

3. Conclusions & Future work

After employing neural network based methodology; the results indicate that the system uses a classification approach and has an accuracy of 90% classification when evaluated against a specialist recommended medical referral decision. The input dataset to the trained Artificial Neural Network obtained from CT scanned images. The results of this at various phases could study could potentially useful to develop further detection and classification system for medical community in terms of predicting patients who are likely to have brain hemorrhages.

Recommendations for Further Study:

1. Study of Severity with aging of the hemorrhages,
2. Analysis of the concept of Fat content and water content can be used in failure of Liver function,
3. Application of Neural network system to be extended on MRI Images,
4. Application of other artificial intelligence techniques such as Bayesian Networks to solve medical diagnosis in brain hemorrhages,
5. Classification algorithm can be improved using Water Content and Fat Content,
6. Application of Data Mining Techniques such as Clustering can be studied.
7. Study about Arterial content and venal content can be carried out,
8. Study of hemorrhage caused by hyper tension or by existing tumor in the brain can be studied using Neural network, and
9. Profiling techniques can be used for finding the location of hemorrhage.

The social problem this research addressed is to provide an initial attempt for detection and classification of brain hemorrhages using Artificial Neural Networks. This may potentially useful for employing telemedicine detection systems.

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An Expert System for diagnosis of diseases in Rice Plant

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Abstract

This paper presents an architectural framework of an Expert System in the area of agriculture and describes the design and development of the rule based expert system, using the shell ESTA (Expert System for Text Animation). The designed system is intended for the diagnosis of common diseases occurring in the rice plant. An Expert System is a computer program normally composed of a knowledge base, inference engine and user-interface. The proposed expert system facilitates different components including decision support module with interactive user interfaces for diagnosis on the basis of response(s) of the user made against the queries related to particular disease symptoms. ESTA programming is based on logic programming approach. The system integrates a structured knowledge base that contains knowledge about symptoms and remedies of diseases in the rice plant appearing during their life span. An image database is also integrated with the system for making the decision support more interactive. The pictures related to disease symptoms are stored in the picture database and the intelligent system module prompts these with the interface based on rule based decision making algorithms. The system has been tested with domain dataset, and results given by the system have been validated with domain experts.

Keywords: Expert System, ESTA, Agriculture, Rice disease, Knowledge Base, IS Experts.

1. INTRODUCTION

In any agricultural production system, accumulation and integration of related knowledge and information from many diverse sources play important role. Agriculture specialists and raw experiences are the common sources to provide information that the different stakeholders require for decision making to improve agricultural production. Agricultural specialists' assistance is not always available when the need arises for their help. In recent years, tools, technologies and applications of information technologies have emerged as efficient and effective measures for upgradation of the whole agricultural fields, ranging from scientific studies to farmers help. Integration of expert system as a powerful tool for the stakeholders of agricultural production has extensive potential.

The main concern of the present study is in the design and development of such an expert system. The system background starts with the collection of disease symptoms of the rice plant appearing during their life span from agriculture experts, plant pathologists and literature and then the acquired knowledge is represented to develop expert system in prolog based expert system shell ESTA.

2. EXPERT SYSTEM IN AGRICULTURE

The applications of expert system are rapidly increasing. Such applications are very affective in situations when the domain expert is not readily available. In agriculture, applications of expert system are mainly found in the area of diseases diagnosis and pest controls. Many domain specific expert systems are being used at different levels. “AMRAPALIKA: An expert system for the diagnosis of pests, diseases and disorders in Indian mango” is an application of expert system in the agriculture domain developed by Rajkishore Prasad, K.R.Ranjan and A.K.Sinha[1]. In this system, the expert system is developed with rule-based expert system, using ESTA. Another expert system “Dr. Wheat: A Web-based Expert System for Diagnosis of Diseases and Pests in Pakistani Wheat,” is also an expert system developed by F.S.Khan, S.Razzaq, K.Irfan, F.Maqbool, etc.[2]. The system is for the purpose of pest and disease control of Pakistani wheat. They had developed the system with web-based expert system using e2gLite shell. “Expert Systems Applications: Agriculture”, is also the application of expert system in the agriculture domain developed by Ahmed Rafea[3]. “Decision Support System “Crop-9-DSS” for Identified Crops”, by Ganesan V. is an expert system developed with Macromedia flash MX Professional 2004 6.0[4]. The system is developed for the purpose of the identification of diseases and pests with control measures, fertilizer recommendation system, water management system and identification of farm implements for leading crops ok Kerela. “Web based Expert System for Diagnosis of Micro Nutrients Deficiencies in Crops”, by S.S.Patil, B.V.Dhandra, U.B.Angadi, A.G.Shankar, and Neena Joshi also describes application of expert system in agriculture particularly in the area of nutrient deficiencies in crops[5]. The system is a web based system using the ServCLIPS tool.

3. DESIGN AND DEVELOPMENT OF EXPERT SYSTEM

The idea behind creating an expert system is that it can enable many people to benefit from the knowledge of one person – the expert. Expert system simulates the judgment and behavior of a human that has expert knowledge and experience in a particular field. In the design and development of this expert system, we are using the shell ESTA. ESTA has the explanation facilities of the questions in the knowledge base and for the given advice. ESTA contains the rules represented in its own syntax for its knowledge base. It consists of the inbuilt facilities to write the rules that build the knowledge base.

In an expert system development, knowledge base development is the most important part. The quality of an expert system depends on its knowledge base. Knowledge Base development with the help of domain specific expert in this expert system is developed with ESTA. The process of developing expert system using ESTA is a multi-step process which aims at developing a domain specific knowledge base. The steps for developing knowledge base in this system are identification of the input problem, knowledge acquisition and representation of knowledge into the knowledge base. We present here a comprehensive description of each of them.

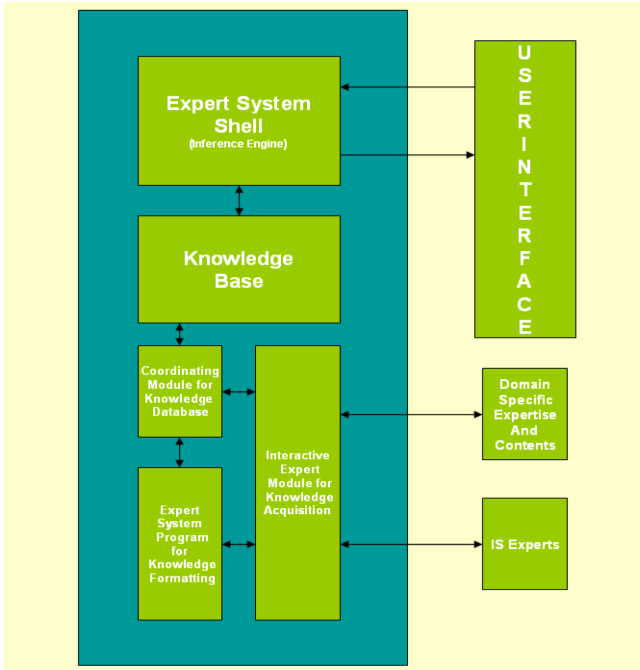

FIGURE 1: Expert System Architecture

3.1 Identification of the Input Problem

To develop an expert system, first we need to identify the problem and understand the major characteristics of the problem that we have to solve in the expert system. The input problem for our system is regarding the diagnosis of diseases in the rice plant occurring during their life span. The input problem is structured for the system and the expert module recognizes as a pattern and forwards for processing for providing diagnoses and remedies if there is.

3.2 Knowledge Acquisition

Acquisition process in this expert system has the following modules-Interactive Expert Module, Expert System Program and Coordinating Module for knowledge database. In the Interactive Expert module, the domain specific expertise knowledge is acquired from human experts. The acquired knowledge is analyzed and then processed to obtain a best conclusion for the problem. The knowledge is then transferred to the IS Experts to verify for converting into expert system program. The process is continued until the best conclusion for the problem is obtained. Once the knowledge acquired from domain expert or domain resources is verified by the IS Experts, then it is transferred from Interactive Expert module to the expert system program module for converting into expert system program. For our system, expert knowledge has been acquired from standard literatures related to the rice plants. "Illustrated guide to integrated pest management in rice in tropical Asia", International Rice Research Institute by W. H. Reissig, E. A. Heinrichs, J. A. Litsinger, K. Moody, L. Fiedler, T. W. Mew, and A.T. Barrion is a literature on rice plant used to get expertise knowledge about rice diseases in the development of the system[6]. In this book, most of the common problems related to the rice plant are described. "Diagnosis of common diseases of rice", by Francisco Elazegui and Zahirul Islam is also used to acquire knowledge about rice diseases in this expert system development[7]. The common diseases of rice plant are found in this book. The processed knowledge in the Interactive module is transferred to the Expert System Program module and then converted into expert system program for formatting and representing the knowledge into the knowledge base. Thus, our Knowledge acquisition process has been carried out through a series of interacting sub modules integrated with the coordinating module for creating the knowledge database until the best conclusion is obtained.

3.3 Representation of Knowledge

Knowledge representation is the last phase of the knowledge base development. In the representation of knowledge into knowledge base, the knowledge acquired from knowledge acquisition process is represented into structured form. There are many approaches for representing knowledge into the knowledge base. Such representation in ESTA is the rule-based representation in logical paradigm of simple ***if-then*** rules in backward or forward chaining. We have chosen here the backward chaining for knowledge representation with simple ***if-do*** pair in place of ***if-then*** rules. Here we have considered two major knowledge representations namely Sections and Parameters. The top level of representation of knowledge in ESTA is section. It contains the logical rules that direct the expert system how to solve problem, actions to perform such as giving advice, going to other sections, calling to routines etc. The first section in ESTA is always named as ***start*** section. The advice is given when condition(s) in the section is(are) fulfilled. Parameters are used as variable and it determines the flow of control among the sections in the Knowledge Base. A parameter can be one of the four types: Boolean or logical, Text, Number and Category parameters. These parameters serve different purposes. Boolean or logical parameter is used when the answer to asked question is either Yes, No, or Unknown. Text parameters are used for text object such as a person's height or favorite film, etc. Number parameter is used for numerical values. Category parameters are used when variable takes more than one of a predefined set of values. The value for any of the parameter is calculated from end-user's response to a question, through other parameters or as a result of application of rules. Any parameter consists of declaration of field, type field and number of optional field such as explanation field, rules field, picture field, question field etc.

The representation of the rules in the main section ***start*** is shown in figure 2. We have developed this section to perform transferring controls in accordance with the user's response. Each section contains classification rules placed in first come first served order. In figure 3, all the fields of a category parameter ***disease_factor*** are shown. The fields in this category parameter ***disease_factor*** are defined as options which are the causing agents of diseases***.***

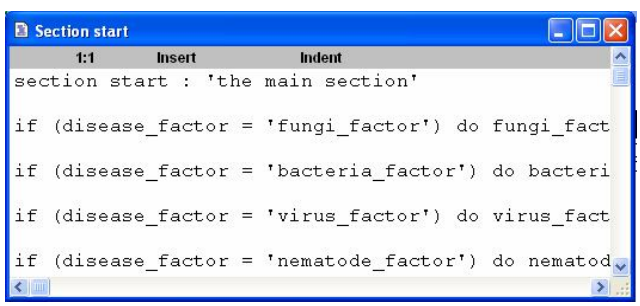

FIGURE 2: Screen shot of the main section *start*

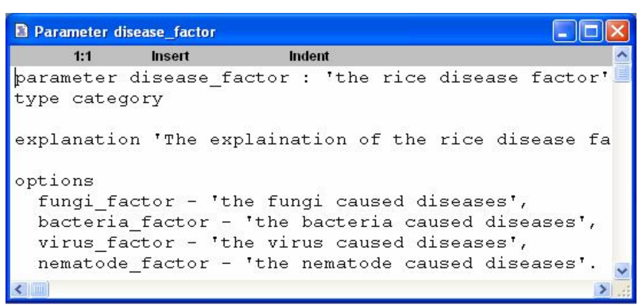

FIGURE 3: Screen shot of category parameter *disease_factor*

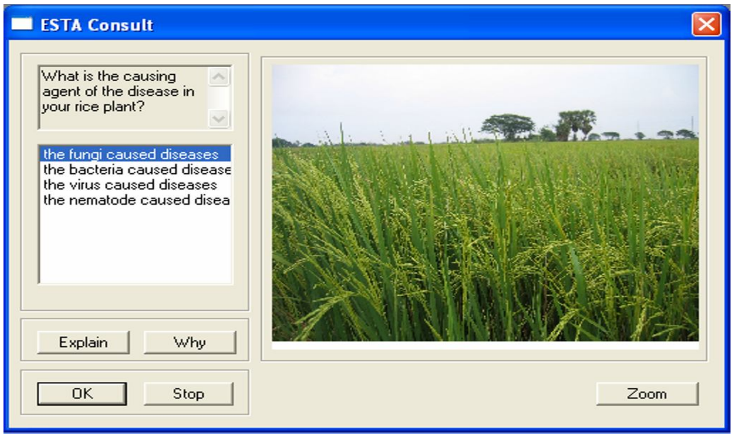

FIGURE 4: Screen shot of rice diseases in ESTA Consult

The interface of the system for the user is shown in figure 4. The left window shows the details of each of the causing agents of the diseases. The feature corresponding to this expert system is placed in backward chain rules including parameters. Each parameter contains explanations for questions, and background rules to decide value of parameters, question statements and pictures related to the particular question of the disease. Design of this system follows top down design approach. The developed knowledge base is stored in the compiled format for faster consultation.

4. CONCLUSION

This paper has presented the architecture, design and development of an expert system for diagnosis of diseases in the rice plant. It is easy to be accessed by the users as the knowledge base is being loaded in the memory in compiled format. Expert system tool forms the start section just after the program runs. This is the main section of the expert system and contains control rule of the system. The knowledge base contains the knowledge about the different diseases of rice plant represented in separate sections. Such system is especially useful for those farmers who are not getting the agricultural specialists at any time for their help to control the problems in their rice plant. The architecture presented here is an integrated system with interactive user interface, control and coordinating units, expert system shells, and structured knowledge representations. The design considered involvements of intermediate interventions in runtime, and also considered dynamic structuring of knowledge representations and rule applier.

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"An Expert System using A Decision Logic Charting Approach for Indian Legal Domain With specific reference to Transfer of Property Act"

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Abstract

Expert systems/ knowledge based systems, a sub-branch of artificial intelligence, are consultative programs, which although limited in flexibility, have achieved levels of performance as comparable to that of human experts. This research sub-branch is now applied in a popular way within both technical and commercial communities. The objective of this research is to develop a legal expert system for transfer of property act, a domain within the Indian legal system which is often in demand. The VisiRule software is a decision charting tool, in which the rules are simply defined by a combination of graphical shapes and pieces of text and is made available by Logic Programming Associates. This comprehensive legal expert system can be of great use for people intending to purchase a property and also to legal experts for fast decision making.

Keywords: Transfer of Property Act, Knowledge Based System, Expert System

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1 INTRODUCTION

Edward Shortliffe, creator of MYCIN, often called the inventor of expert system, observed more than 20 years ago, doctors will not use an expert system, and no matter how good the advice it gives, unless it saves them time. The authors feel that same is also true of lawyers. The building of legal expert systems, most of the time, is for the specific users. The choice of a specific type of user influences the way the expert system is built in law. It is possible to create expert systems in law directed towards the general population also. These legal expert systems can be a vehicle for spreading legal knowledge previously monopolized by legal experts, amongst a wider audience. Hence the authors of this paper decided to build ***TPA-EXPERT*** *(Transfer of Property Act - Expert System).* The aim was to apply artificial intelligence to law, and also, to propagate legal knowledge among 'common' people. We made the choice of the specific act of Indian Legal domain i.e. Transfer of Property Act which is frequently sought after by the common man. The authors selected a legal domain in which a consensus among lawyers exists as the rules are very specific. Though we have not aimed our work at supporting experts, it still will help them in making fast productive decisions.

1.1 Background & Related Work

Representation of regulations and laws has been an active research area for quite long time now **[4, 5].** The work on legal expert systems began in the US with James Sprowl in late 1970s. Ten years later (1989) there was an international conference edited by Marino with contributions from all over the world. Generally, expert systems in law are built for lawyers by the researchers in the computer domain. The rules are collected from the lawyers who are repository of formalized legal knowledge. Expert systems in law are now in use on a regular basis as well as on experimental basis in many instances of the administration of justice within the Indian courts**[11].** The research work on expert systems in law, over the last three decades (1980-2009) have been pioneered by Ken, Ashley, Bench - Capon, J.A., Susskind, R., Henery Prankeen, Tom Gordon to name but a few**.** T. Bench-Capon provided a review on the applications of knowledge-based systems for legal applications **[1, 2].** The reference includes several hundreds of citations that appeared before 1990 which are related to logic and rule based approaches and their application in legal systems. The earlier work in IT and law were directed on building systems to optimize decisions with respect to laws, particularly tax law **[8].** Some of the recent work has focused on investigations into case-based reasoning and information retrieval **[3, 13].** Methodologies on tailoring legal documents to users' needs have also been studied **[12].** This research focuses on the issues related to the development of a regulatory information management infrastructure that can also support compliance assistance.

1.2 Legal knowledge

The authors selected the specific domain of Transfer of Property Act 1882 of Indian legal domain for three main reasons. Firstly, everyone is faced with a land/housing problem at least once in their life time. The transfer of property act is a legal domain which affects people in their day-to-day lives over the buying and selling of property. The Indian property-law, which is substantially codified, is contained in different enactments dating from about the year 1882 till this date, with no less than 1 Lac cases per year. We hypothesized that more accessible legal knowledge about transfer of property act would help people settle case conflicts in a more positive way than any tribunal could. Thirdly, legal expertise was more accessible for one of the authors of this paper.

1.2.1 Non-law Literates

There are very few Legal Expert systems for non-lawyers. The researchers of this paper have chosen non-experts as users for this study. As stated earlier, the authors wanted to investigate the feasibility of propagating legal knowledge to the general population through new technological means. Hence the authors expected that a legal expert system would be a good means of giving people safe and accurate information about buying and selling of property.

2. BACKGROUND

2.1 Legal aspects and related terminologies

In law ‘property’ is defined as “any entity which can be owned”. Thus, right of ownership may be exercised by a person against a property. A ‘person’ is ‘any entity which has rights and duties under law’. A person may be a natural person (a human being) or an artificial person (such as a company, a corporation, etc.). ‘Ownership’ is a right by which the property belongs to the owner to the exclusion of all others. In fact, it is a collection of rights which the owner has against the property owned by him. Right of possession and enjoyment, right of alienation, right of destruction, etc. are some of the rights which an owner can exercise against his property, subject to the laws of the land and rights of others. ‘Title’ is the evidence of ownership, and a ‘title deed’ is a document that shows how and when a person became the owner of a property.

Transfer of property means transfer of some or all of the rights of owner in respect of a property to some other person. If the transfer is of all the rights of the owner, the transfer is a complete transfer of property; else it is a partial transfer of property. ‘Sa*le’*, ‘*exchange*’ and ‘*gift’* are complete transfers of property, while ‘*lease’* and ‘*mortgage’* are examples of partial transfers of property. Once the owner transfers his property by way of a complete transfer, he ceases to be the owner and the transferee becomes the owner.

The transferor loses his right of transfer and the transferee gets the right of transfer. In case of partial transfer of property, the transferor continues to be the owner and hence, retains the right to transfer the property, subject to the rights of the transferee. For example, if the landlord sells the property leased by him to a tenant, the purchaser will purchase the property subject to that lease. So also in case of mortgage the purchaser will purchase the property subject to the mortgage. In other words, the transferee always gets the same rights and obligations of the transferor in respect of the property transferred to him. Such obligations subject to which the property is transferable are called the *‘encumbrance’* over the property. A transferee has to see that the transferor has the authority to transfer the property, and that there are no encumbrances attached to the property.

Under sec. 17 of the Indian Registration Act, a deed witnessing transfer of an immovable property must be compulsorily registered; otherwise it cannot be admitted in evidence. Therefore, if the transferor has received a property under an unregistered transfer deed, it will be impossible to prove that he had title to the property. Therefore, the transferee will not be able to prove that he has received a good title from the transferor whose title itself cannot be proved. Hence, registration of the deed under which the transferor has received the property is one of the most important aspects to be verified.

Sale, exchange, gift, lease, mortgage are transfers ‘*inter vivos’*, i.e., transfers by one or more living persons to one or more other living persons. If the owner of a property does not transfer his property to any other person during his life time, the property devolves upon his successors after his death, by way of succession. Succession may be ‘*testamentary succession’* or ‘*intestate succession’*. If the deceased owner of the property leaves behind him a valid will and expresses his desire to give that property some person after his death, the property devolves upon that other person, called the *‘legatee’*, by way of testamentary succession. If the deceased does not leave behind him a valid will the property devolves upon his heirs by way of intestate succession. So also even if the deceased has left behind him a valid will, but has not provided for devolution of a particular property in that will, the property not covered by the will devolve upon his legal heirs. This is called *‘partial intestacy’*. In case of a will a *‘probate’* is to be obtained to prove the genuineness of the will. Once a probate is granted by a competent Court, it is conclusive proof of the fact that the will is genuine. Therefore, one can purchase the property from the legatee to whom it is gifted by the deceased. In case of intestate succession, one of the heirs may obtain *‘letters of administration’* from a competent Court. He is called the *‘administrator’* of the estate of the deceased and is competent to transfer the properties of the deceased. However, now obtaining probate or letter of administration is not compulsory. In lieu of them one may obtain a succession certificate from a competent court.

Once it is proved that the transferee has the title to the property, it is also necessary to verify whether the person from whom he has obtained the property had a clear and marketable title to the property. If he did not have one, then the transferor cannot have one, as already seen above. In such a case the true owner may file a suit for setting aside the transfer and the transferee will be deprived of the property. Though he may file a suit for recovery of the money he has paid to the transferor, it will be an unnecessary trouble which may be avoided by taking a little care. It is to be noted here that though the original owner can file a suit for setting aside the transfer, he can do so within twelve years from the date of transfer of his property by a third party. Therefore, if the transferor has purchased the property more than thirteen years ago, suit against him will be time barred, and no special precaution is necessary. Otherwise, the suit will be well within limitation prescribed by the Limitation Act, and the flow of title of the property will have to be traced for the last thirteen years by looking into the Record of Rights maintained by the Revenue Authorities.

The transferee in case of a transfer *inter vivos*, and a legatee or legal heir in case of succession is having title to the property. Now once the title to the property is established, it is necessary to examine whether the property is free of encumbrances. For that purpose one has to obtain a *'Nil Encumbrance Certificate'* from the Sub-Registrar's office within whose jurisdiction the property or any part of it is situated. If there is encumbrance on the property, such a certificate will not be issued.

Further, if the transferor has not paid the taxes in respect of the property to the respective public authorities, the Government will have a charge over the property, and the money may be recovered by forfeiture or by attachment and sale of the property even in the hands of the transferee. Therefore, it is imperative to verify that the transferor does not have any tax dues, by looking into the up-to-date tax paid receipts **[6].**

This is, in short, the procedure for verifying the title to the property to be purchased, and of verifying that it is free from encumbrances.

2.2 How to trace title

Tracing the flow of title of the property is the most important part of the investigation of title. Thorough knowledge of the various aspects of law especially civil law is a must for this. Law relating to Minors and the legally disabled; Law of Succession, both inter vivo and intestate; Different land tenures prevalent in the locality; Special Statutes like the state Land Reforms Act, The Schedule Tribes Act, The Land Assignment Act the modes of obtaining title through decrees of Court etc., are to be thoroughly known to the investigator in order to make a proper tracing of title of the property.

2.2.1 Transactions in immovable property are carried out by parties in properties containing the following elements:

- Original owner.
- Intermediary owners.
- Promoter.
- Developer.
- Contractor.
- Investor.
- Marketing agency.
- Prospective buyer.
- Lending institutions.
- Association of Owners.

The following are the nature of properties:

- Land.
- Houses.
- Flats/apartments.
- Infrastructure.
- Special amenities and facilities.

The following are the nature of rights:

- Ownership.
- Possession.
- Leasehold rights.
- Rights under a mortgage.
- Easement.
- License.
- Lien.

3. RESEARCH METHODOLOGY ADOPTED

Identifying the knowledge used in decision making or problem solving is a very crucial component of the expert system design **[7].** The research methodology used for the comprehensive development of rule based expert system is as follows **[9]**

- Literature survey of different software available for the development of the expert system.
- Continued interaction and discussions with the advocates and Professors in Law schools.
- Conceptualizing the rules in required format.
- Implementation and testing the rules using VisiRule.

3.1 Evaluation of technology used for implementation.

The authors of this paper have studied most popular expert systems shells available such as Clips and Jess. These shells were used by the authors for prototype development in the Transfer of Property Act**[10].** The researchers also studied other rule engine options such Drool, Eclipse, Sweet Rules and VisiRule. The authors finally selected the last option, i.e. VisiRule, for the development of expert system. One of the major drawbacks of conventional expert systems is that they are largely text based and require some technical skills in using their often proprietary rule syntax. Logic Programming Associates, the authors of VisiRule, offer the Flex expert system toolkit which is a versatile, extendible development tool based in logic and with access to the underlying Prolog programming language. However, even with it's highly readable English-like knowledge specifications language, Flex still requires domain experts to read and write rules as individual items of text using a specialized syntax and remember the connections between them. VisiRule overcomes these issues by presenting a graphical environment where rules are simply defined by a combination of graphical shapes and pieces of text. The potentially intricate structuring of the application logic is presented as a diagram which can be editing as one. By adopting and enhancing the well established metaphor of the flow chart, VisiRule allows experts to concentrate on exploring and establishing the structure of the logic rather than worry about how to encode the logic correctly using their chosen tool. The resulting diagram is readily available to domain experts, i.e. legal practitioners, without having to involve technical experts, namely programmers. This opens up the discussion to a much wider audience, and actively encourages participation by more interested parties. As the adage states, a picture is worth a thousand words. It also helps avoid some of the errors which can come into play when trying to code logic in a text based rule language.

4. EXAMPLE STUDY CARRIED OUT WITH VISIRULE

The authors of this study carried out the development of the prototype as mentioned earlier in Clips and Jess. The development of the prototype was done and proper verification and validation by the legal experts was carried out. The extensive developmental study of the modules was conceived and the VisiRule software was selected for the development purpose. The authors have developed 10 modules covering all aspects of transfer of property act in Indian legal domain. The modules in total consist of nearly 90 rules. As space is constrained, the authors have considered including only one module in this paper.

4.1 Visirule implementation of the module-1 mentioned above is given below.

In this module the authors discuss one of the aspects of tracing the title of property i.e. is the transfer of property by TRANSFER or by SUCESSION. This further leads to finer aspects and in the subsequent part the authors check by asking the user nearly 10 question which have been indicated in the yellow box. The red box indicates the conclusion (i.e. either the property can be purchased or not) drawn after series of inferences. The white boxes indicate options to be selected by the questions. The decision chart below is the representation of the one of the module developed by the authors.

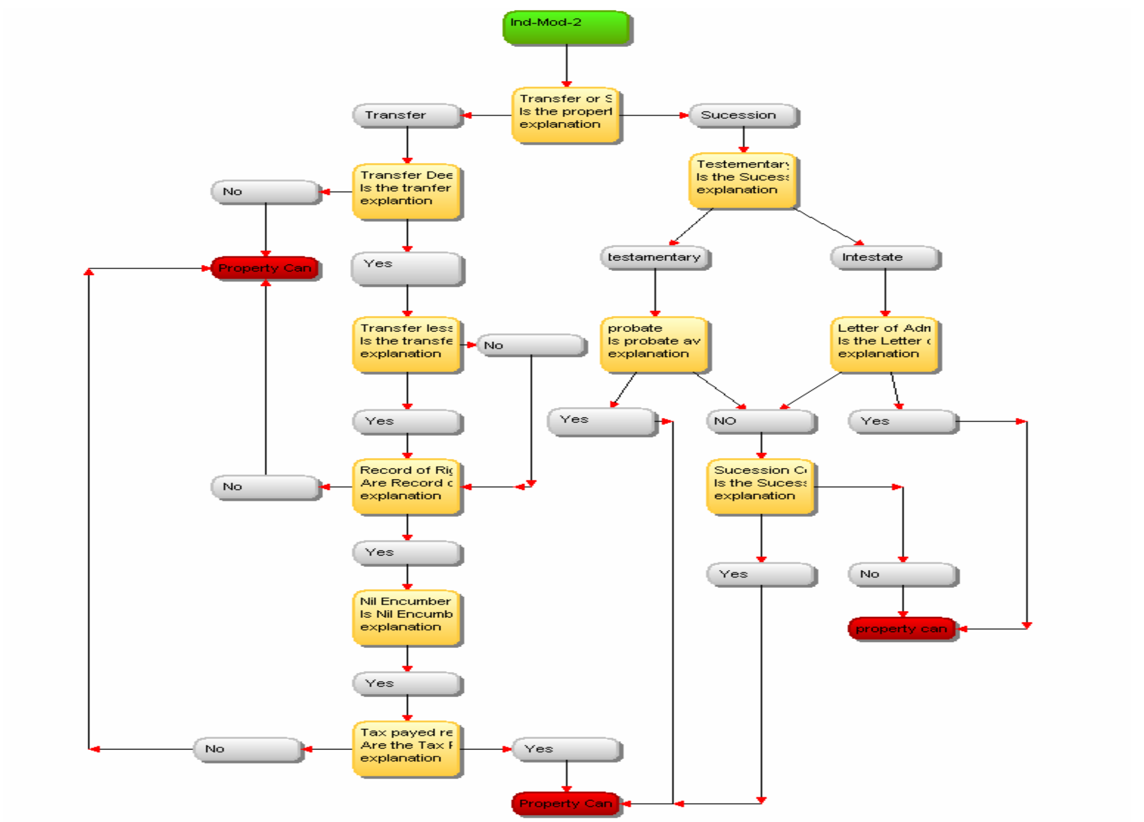

Fig 1: VisiRule Implementation Module-1

4.2 Comments of use of Decision charting approach

Despite the usefulness of incorporating the rule based reasoning using visirule which has decision charting approach, it was noticed that some terminology in law which are synonymous could be interpreted differently. Hence it is desired to check the implementation of rules properly.

5. CONCLUSION

In the first phase of this research work the authors have developed the prototype for the expert system in transfer of property act in Indian legal domain. The second phase of the work the authors have undertaken the development of a comprehensive expert system. This research paper also looks into the work that has been done to date on development of legal expert systems. Hence the authors feel that **TPA-EXPERT** research work, can benefit both the non-law literate who intend to purchase a property and also for experts in the field of law for productive and fast decision making. The system can be further improved from enriched consensus knowledge of experts as well as multiple lines of reasoning.

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Forecasting Electric Energy Demand using a Predictor Model based on Liquid State Machine

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Abstract

Electricity demand forecasts are required by companies who need to predict their customers' demand, and by those wishing to trade electricity as a commodity on financial markets. It is hard to find the right prediction method for a given application if not a prediction expert. Recent works show that Liquid State Machines (LSMs) can be applied to the prediction of time series. The main advantage of the LSM is that it projects the input data in a high-dimensional dynamical space and therefore simple learning methods can be used to train the readout. In this paper we present an experimental investigation of an approach for the computation of time series prediction by employing LSMs in the modeling of a predictor in a case study for short-term and long-term electricity demand forecasting. Results of this investigation are promising, considering the error to stop training the readout, the number of iterations of training of the readout and that no strategy of seasonal adjustment or preprocessing of data was achieved to extract non-correlated data out of the time series.

Keywords: Liquid State Machine, Pulsed Neural Networks, Prediction, Electric Energy Demand.

1. INTRODUCTION

Prediction of time series is a very important task in different scientific disciplines [1,2]. Temporal patterns is central to any domain in which time-series data are collected and analyzed with the purpose of making enhanced predictions about the likely outcomes of observed trends or identifying recurrent patterns. Electricity demand forecasts are required by companies who need to predict their customers' demand, and by those wishing to trade electricity as a commodity on financial markets.

Weather forecasts involves matching a temporal pattern to a classification, whereas predicting the temperature, humidity and barometric pressure requires a more complex function, or at least a function with a greater range of outputs. In general, prediction infers the future states of multiple variables based on the historical states of those variables. This problem has been widely studied by researchers in different areas attempting to build models which will provide useful indications of the complex behaviors of systems like markets, populations, atmospheres and ecologies [3-5].

Artificial Neural Networks (ANNs) are a method used to simulate various traditional approaches to time-series prediction, such as curve-fitting, linear regression, and even AutoRegressive Moving Average (ARMA) stationary stochastic models [6]. The traditional application of these techniques, the building of time-series functions for specific phenomena, is difficult and time-consuming. Neural networks have shown reasonable success in approximating these non-linear functions and their parameters, and while they themselves can require the tuning of many parameters, they promise to greatly enhance the speed with which such analysis may be conducted. A popular approach using ANNs is to learn the prediction from previously collected data. The advantages are that knowledge of the internal structure is not necessarily needed, arbitrary nonlinear prediction could be learned and additionally some past observations could be integrated in the prediction.

Although classical ANNs have been shown to be quite powerful in many domains, their structure is not very well suited to represent temporal patterns [7]. In order to deal with temporal data, one of the possible solutions is to use Recurrent Neural Networks (RNNs). In such recurrent networks connections are incorporated enable the flow of back information for future time steps. Using this recurrence, dynamic temporal patterns can be registered by the network over time. This produces some kind of internal memory that allows obtaining complex functions. This is a central feature for networks that will be used for prediction of time series, because a current output is not solely a function of the current sensory input, but a function of the current and previous sensory inputs and also of the current and previous internal network states. This makes possible a system to incorporate a much richer range of dynamic behaviors.

However, exactly these internal temporal dynamics make it much harder to train the network. The training problem consists of adjusting the parameters (weights) of the network so that it can provide a specific answer for a series of inputs [8]. In order to solve the task of training in RNNs, [9,10] proposed an approach under the name of Reservoir Computing (RC) [11].

Reservoir Computing is a recent architecture for RNNs composed by two main modules. The first one is the 'reservoir' which is a RNN where the recurrent connections are not trained at all. The reservoir is a randomly generated dynamic system with unchanged weights. The training is performed only at the second stage, called 'readout' [10]. RC produces rich dynamics of temporal nature and has been used as a powerful tool for the computation on time series [1,12-14].

In recent years, data from neurobiological experiments have made it increasingly clear that biological neural networks, which communicate through pulses, use the timing of these pulses to transmit information and to perform computation. Based on the RC, Maass and colleagues [9] proposed the Liquid State Machine (LSM) using a reservoir of pulsed Neural Networks (NNs) with integrate-and-fire neurons in combination with simple learning algorithms at readout stage. However the temporal dynamic associated with the treatment of continuous time series is still a challenge for pulsed NN.

In this paper we propose a predictor model using LSM for continuous temporal series prediction applied in electricity demand forecasting. We analyze the dynamic of the network, focusing in the treatment of the temporal memory reset and the conversion of the continuous temporal signal in a set of pulses for pulsed NN. Our approach is validated in an electricity demand forecast, which is an important challenge for the economic and secure operation of power systems. We describes a prediction method based on LSM applied to a time-series of CEEE (Companhia Estadual de Energia Elétrica do Rio Grande do Sul, Brazil).

The remainder of this paper is organized as follows. The next section provides an overview of the LSM. Section 3 presents the architecture of LSM used for this work and the description of the simulation carried out. The accomplished experiments and associated results are presented in Section 4. Finally, the last section summarizes and concludes this work.

2. THE LIQUID STATE MACHINE

2.1 The framework of a Liquid State Machine

The Liquid State Machine (LSM) has been proposed by Maass and colleagues [9] as a new framework for neural computation based on perturbations [15]. A LSM uses an excitable medium to transform low-dimensional inputs into a high-dimensional 'liquid', so that simple readout unit can extract more detailed temporal features from the input data. Its function resembles a tank of liquid: as the inputs disturb the surface they create unique ripples that propagate, interact and eventually fade away. After learning how to read the water's surface we can extract a lot of information about recent events, without having to do the complex input integration ourselves [16].

To understand the basic idea behind LSMs imagine a pool of water into which various objects are dropped. As the objects enter the liquid, they perturb its surface. The resulting splash and ripples that are created can be transformed in real-time into 'liquid states' (a spatio-temporal pattern of liquid displacement). These ripples propagate over the water's surface for a while and will interact with the ripples caused by other recent events. The water can thus be said to retain and integrate information about recent events, so if we're somehow able to 'read' the water's surface we can extract information about what has been recently going on in this pool. We refer to this trained spectator as a readout unit that we can ask at any one time what's going on in the pool, provided that we can show him a snapshot of the liquid's surface [16].

Thus, LSMs are composed of two parts: a Dynamical Liquid Unit - a model of dynamic liquid flow that is used as a 'reservoir' of complex dynamics to transform the input time series $u(\cdot)$ into 'liquid states' – and a Readout Unit – a simple function which maps the liquid state at time t onto the output.

The idea of the Maass' LSM [9] is shown in figure 1. A continuous input stream $u(\cdot)$ of disturbances is injected into excitable medium L^M that acts as a liquid filter. This liquid can be virtually anything from which we can read it's current liquid state $x^M(t)$ at each time step t. The liquid state is mapped to target output function $y(t)$ by means of a memory-less readout function f^M. This readout map f^M is in general chosen in a task-specific manner (and there may be many different readout maps, that extract different task-specific information in parallel from the current output of L^M) [9,16].

2.2 The Dynamical Liquid Unit

A model of dynamic liquid flow can be implemented using recurrent Spiking Neural Networks (SNNs) which are very powerful tools for solving complex temporal machine learning tasks [17].

The liquid is a non-linear dynamical system composed of a set of spiking neurons pool that receives time-varying input and transforms these different temporal inputs into significantly different liquid states. The task-dependent part is executed by the readout unit that can be trained to extract information from the liquid state transforming this information into a useful form, e.g. into a prediction. The pool of neurons (figure 2) is composed by $N = n_x \times n_y \times n_z$ neurons placed on a regular grid in 3D space. The number of neurons along the x, y and z axis, n_x, n_y and n_z respectively, can be chosen freely [1].

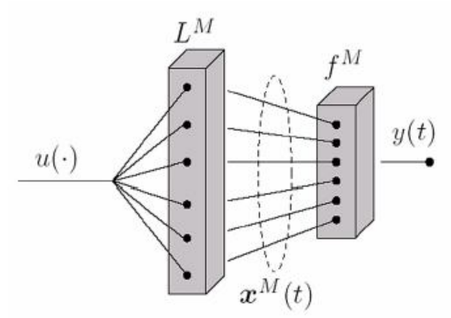

FIGURE 1: Architecture of a LSM [9].

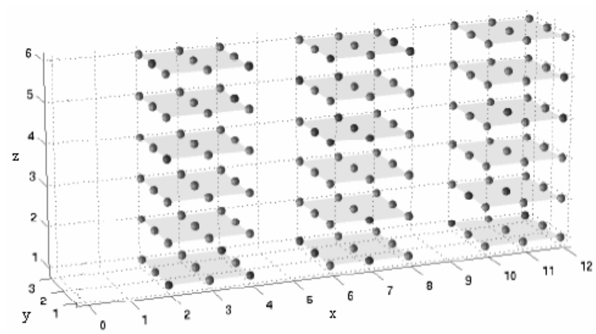

FIGURE 2: Example of the structure of liquid middle of a LSM, formed by a pool of 3×3×6 neurons [18].

2.3 The Readout Layer

The readout units must be capable of detecting stable features between a set of patterns. This unit receives the high-dimensional inputs from the liquid and takes as input the instantaneous reservoir state, i.e. the collection of all of the states of the individual elements, and produces an output decision [16].

A miscellaneous of implementations to the readout unit in LSMs can be achieved [16]. However, a readout unit consisting of just single neurons can obtain nearly the same results as more sophisticated units like pools of perceptrons [19]. Dual liquid-readout modules can also be implemented. In cases where the target output consists of slowly varying analog values, a single readout neuron can be trained to represent these values through its time-varying firing rate [9]. In addition, a low-pass filter can be applied to transform the spike trains into continuous output that can be weighted and fed to an analog readout [16]. In any case the readout neurons can be trained to perform a specific task by adjusting the strengths of synapses projected onto them from the liquid neurons [9].

2.4 Using a LSM: Features and Issues

The LSM works as follows. The input signal $u(\cdot)$ feed the reservoir (pool of neurons). This signal stimulate the neurons in the pool which acts as a filter and the input signal is then transformed into another signal that encapsulates the dynamics of the liquid. Samples of the state of the liquid are taken and form a sequence of vectors, called state vector, which can then be used to train a readout function. Finally, the readout function can be trained using these state vectors to represent the inputs [20].

As a SNN projects the input into a high-dimensional space, the learned readout function can be simple. Also, any snapshot of the state of the network contains information about both current and past inputs; the waves of spikes produced by input in the past continue to propagate for some time, intermingling with the waves from the current input. This process is referred to as integration of inputs over time. When a network properly integrates inputs over time, a readout function can be memory-less, relying on the network to remember and represent past and current inputs simultaneously [20].

2.4.1 Training

The original LSM concept stated that the dynamic reservoir states can be processed by any statistical classification or regression technique [21]. The key idea underlying LSM (RC) is to train, by supervised learning, only the readout unit while the liquid has fixed weights [17]. The training thus consists of a linear regression problem, which can easily be solved in a way to find the global optimum (for a given reservoir). Therefore, only the readout needs to be trained according to the task. It is not necessary to take any temporal aspects into account for the supervised learning task since all temporal processing is done implicitly in the liquid [22]. Pruning connections from the liquid the readout unit can be used to selecting subsets of variables (i.e. neurons in the reservoir) which are the most relevant for a given target output [23].

2.4.2 Separation and Approximation Properties

An essential requirement of the LSM architecture is that different inputs sequences into the liquid must result in separable outputs based on the liquid's response. The amount of distance created between those is called the Separation Property (SP) of the liquid. The SP reflects the ability of the liquid to create different trajectories of internal states for each of the input classes. The ability of the readout unit to distinguish these trajectories, generalize and relate them to the target outputs is called the universal Approximation Property (AP) of the readout. This property depends on the adaptability of the chosen readout unit, whereas the SP is based directly on the liquid's complexity [16].

Natschläger and colleagues [22] described these two conditions as necessary for computations in time series using LSMs. For this reason, it would be imperative is to create a liquid that effectively separates classes of input into different patterns of state vectors. Besides, the readout must have the capability to distinguish and transform different internal states of the liquid into given target outputs. Schrauwen and Verstraeten [21] mention that the approximation property is satisfied by a simple linear regression function. Since the AP was already close to optimal, the primary limitation in performance lay in the SP [9].

There are so far no design principles to create an 'ideal' liquid state for a special type of input [24]. SP can be engineered in many ways such as incorporating neuron diversity, implementing specific synaptic architectures, altering liquid connectivity, or simply recruiting more columns for neural implementations [9]. Although, Buonomano and Merzenich [25] had already shown that generic recurrent circuits of integrate-and-fire neurons are able to transform temporal input patterns into spatial activity patterns of the circuit. Consequently, it suffices to verify that such recurrent circuits have the SP [26].

The effectiveness of the liquid architecture is affected by a large number of parameters such as size of the reservoir, node types, input connectivity and recurrent connections. These parameters determine the short term memory and separation capability of a reservoir [27]. An inadequate set of parameters limits the potential of the liquid. Thus, the parameter selection has been the topic of much research [11,28,29]. In general, optimization of LSM parameters for applications is based on experience and heuristics and partly on a brute-force search of the parameter space [21].

2.4.3 Interference and Initalization

Closely related to the effectiveness of the liquid is a characteristic of the LSM which generates interference between successive input signals, so that they are merged and transformed into a combined representation. Consequently, the current input and the input history determine the liquid response, due to the recurrent connections. Knüsel and colleagues [30] and Vink [31] showed that a reset mechanism is an essential component to improve the network performance, since the temporal mixing of information from past and present stimuli can compromise the results. They verified a critical dependence between the initial state of the network at stimulus onset and its internal state after stimulus presentation. Thus, in order to improve the performance, a system initialization at stimulus onset could be required.

2.4.4 Features and Issues associated with the use of LSM

In the next section we propose an approach to predict continuous time series. We introduce the general setup that was used during our experiments to solve the prediction with real-world data from the time series provided by the CEEE (Companhia Estadual de Energia Elétrica do Rio Grande do Sul, Brazil).

3. LSM PREDICTION

3.1 A LSM Architecture to Deal with Continuous Time Series Forecast

This paper describes a model for predicting continuous time series using LSM. The proposal is applied to a case study associated with forecasting future electricity demand.

The architecture of the LSM used in our approach consists of four different modules as seen in figure 3: an input layer that is used to feed data into the liquid, a pool of neurons forming the liquid, an exponential filter that decode the liquid response, and the readout unit which computes an output using the membrane potentials obtained from the liquid neurons.

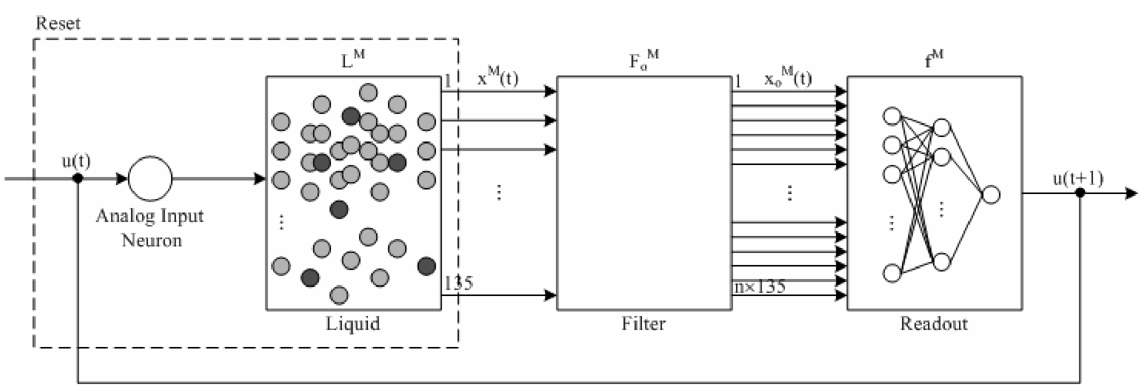

FIGURE 3: Architecture of LSM used in experiments.

The Input Layer. The input layer is an excitatory analog input neuron connected by a static analog synapse to all neurons in the liquid middle scaled to a spectral radius of $|\lambda_{max}| = +\infty$, and $C_{Scale} = +\infty$ with the strength of the synaptic connections scaled to $\lambda = 0.05$. The parameter C_{Scale} specifies how to scale the overall connection probability [9,32], $C_{Scale} = +\infty$ ensures that there will be a synaptic connection between each pair of neurons in the source region and the destination region [18].

The Dynamical Liquid Unit. The liquid L^M (reservoir) consists of a recurrent network composed by a pool of dimension 3×3×15 (135) integrate-and-fire neurons randomly connected via dynamic spiking synapses scaled to a spectral radius of $|\lambda_{max}| = 3$ and $C_{Scale} = 1$ with the strength of the synaptic connections scaled to $\Omega = 1$. Randomly, 20% of the neurons are chosen to be inhibitory.

The Decoder Filter. The liquid response $x^M(t)$ (i.e. the set of all spike times of the neurons in the liquid) is decoded into the liquid state $x_o^M(t)$ (analog values) using an exponential filter f_o^M before being fed into the readout unit f^M.

The Readout Unit. The readout unit consists of a Multi-Layer Perceptron (MLP) network. The input layer of the readout consists of $n \times 135$ sigmoidal neurons, where n is the number of sample time points. We sample the state every 100ms. The output layer is a single linear neuron. The hidden layer is composed by 50 sigmoidal neurons. This number of neurons was defined empirically. The readout unit was trained by the Resilient Backpropagation (RPROP) algorithm. It is possible to use a feedback to store the context of the sequence dynamically. In this context a feedback loop is incorporated in order to flow back information for future time steps.

The experiments were done using CSIM (a neural Circuit SIMulator) which is a tool that can simulate heterogeneous networks constituted by different neurons and the synapses, it is written in C++ language with an interface to Matlab®[32]. The multi-'column' neural microcircuits construction is allowed by the Circuit-Tool while the Learning-Tool can analyses the real-time computing in the neural microcircuit models [18,33].

3.2 Simulation

For training and testing the analog time series is split in two parts: 80% for training, and 20% for validation and testing. The time series needs to be normalized to the interval [0, 1], otherwise all neurons would be saturated and thus loosing information. The input vector $u(t)$ is composed of the current input at time step t and the last 14 inputs in the sequence resulting in a vector of fixed length (15 inputs) to represent the past context. This approach builds a predictive model that uses information from the entire sequence, although the vector has a finite length. The size of the vector $u(t)$ was defined by inspecting the seasonality of the time series.

To feed activation sequences into the liquid the input data are provided as vectors of continuous values between 0 and 1, from a single input neuron. The liquid's activity generates a set of 135 state vectors $x^M(t)$ as output. These state vectors are decoded by the filter f_o^M and projected onto the readout unit f^M which predict the value at the time step t+1. The LSM is initialized and reset prior to the presentation of each sequence. Comparing the prediction performance with and without resetting the network reveals that the latter outperforms the former.

The Mean Square Error (MSE) was introduced to evaluate the performance of the method. The evaluation of time series y and its prediction $\hat{y}$ considering N predictions is done by:

$$MSE = \sum_{t=1}^{N} \frac{(y_t - \hat{y}_t)^2}{N}$$

4. EXPERIMENTAL RESULTS

The approach described in the previous section has been applied in seven different experiments to obtain the forecast of electric energy demand in state of Rio Grande do Sul (Brazil). Figure 4 presents the electric energy demand in Rio Grande do Sul (Brazil) for ten years (1998 – 2008). The plot shows that data are marked by a temporal dependence characterizing seasonality. The period November 2006 – September 2008 (20% of the analog time series) has been chosen as a test set to check the forecasting errors and to validate the proposed method.

The experiments 1 and 2 consisted in to predict one time step ahead based on an input vector $u(t)$ composed of the currrent input at time step t and the last 14 inputs in the sequence resulting in a vector of fixed length (15 inputs) representing the past context. The experiments 1 and 2 were achieved without feedback and with feedback respectively. The next 23 samples were predicted based on training set of 92 samples. We used the sigmoidal normalization. The readout was trained until the convergence to the goal after 60 epochs considering an error of 0.001. Figure 5 shows a plot of the network output compared to the target output with feedback and without feedback.

The experiments 3 and 4 were carried out using the same data as described for the experiments 1 e 2, but the readout was trained until the convergence to the goal after 68 epochs considering an error of 0.0005. The experiments 3 and 4 were achieved without feedback and with feedback respectively. Figure 6 shows a plot of the network output compared to the target output.

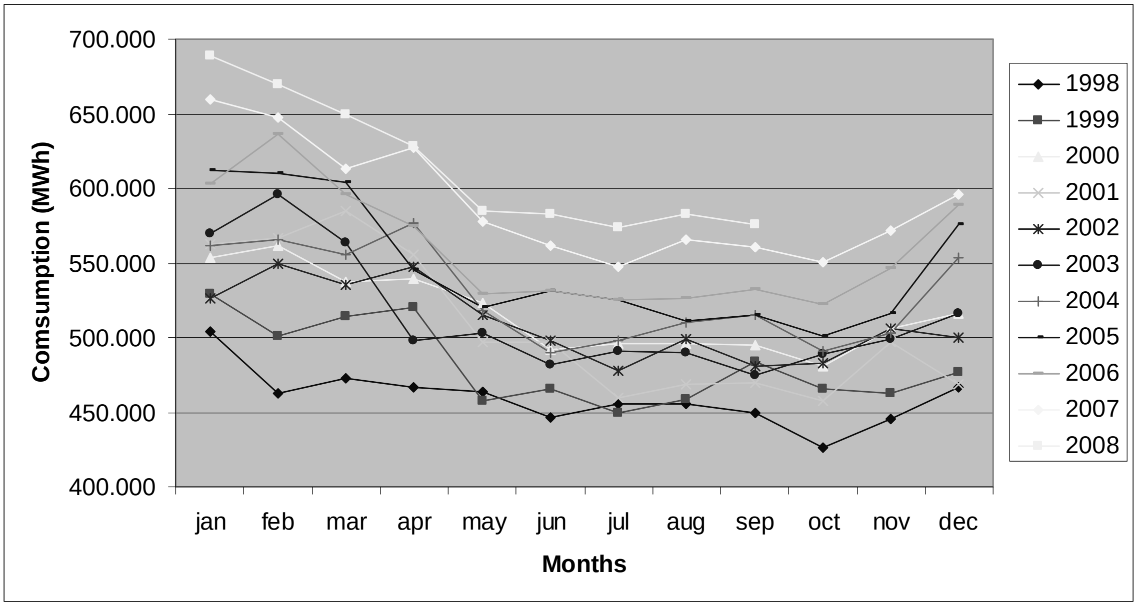

FIGURE 4: Rio Grande do Sul (Brazil) electric energy consumption for ten years (1998 – 2008).

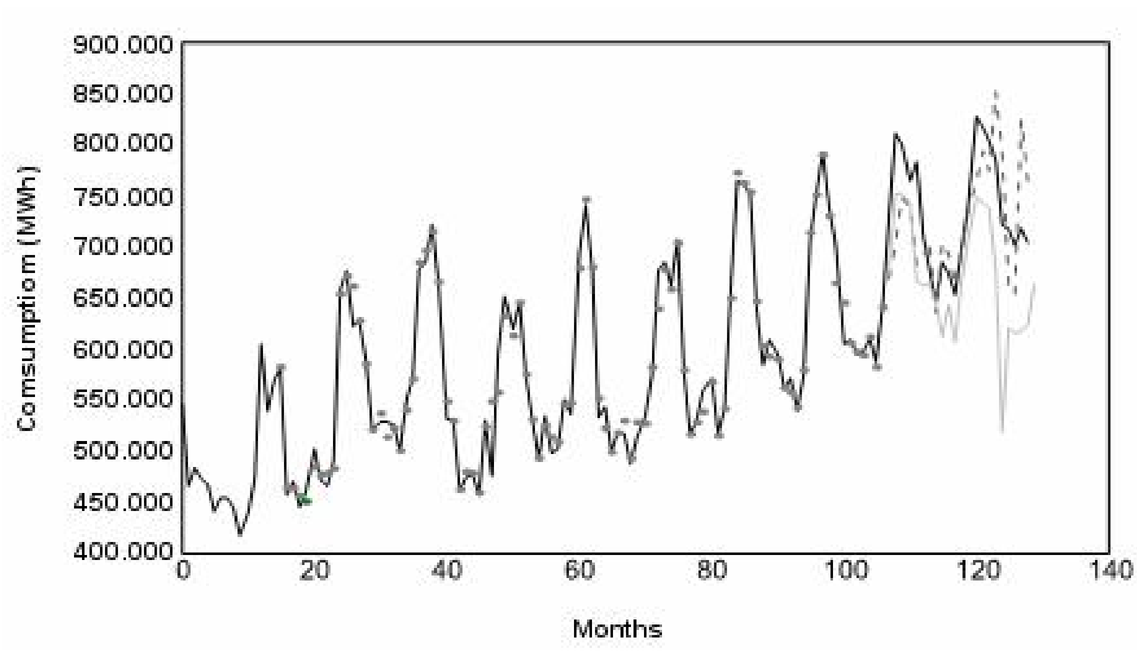

FIGURE 5: Network output versus the desired output for the experiments 1 and 2 training the readout to an error of 0.001. Solid dark gray line: original series, gray points: output of the network for the training set, dashed line: network output without feedback (experiment 1), light gray line: network output with feedback (experiment 2).

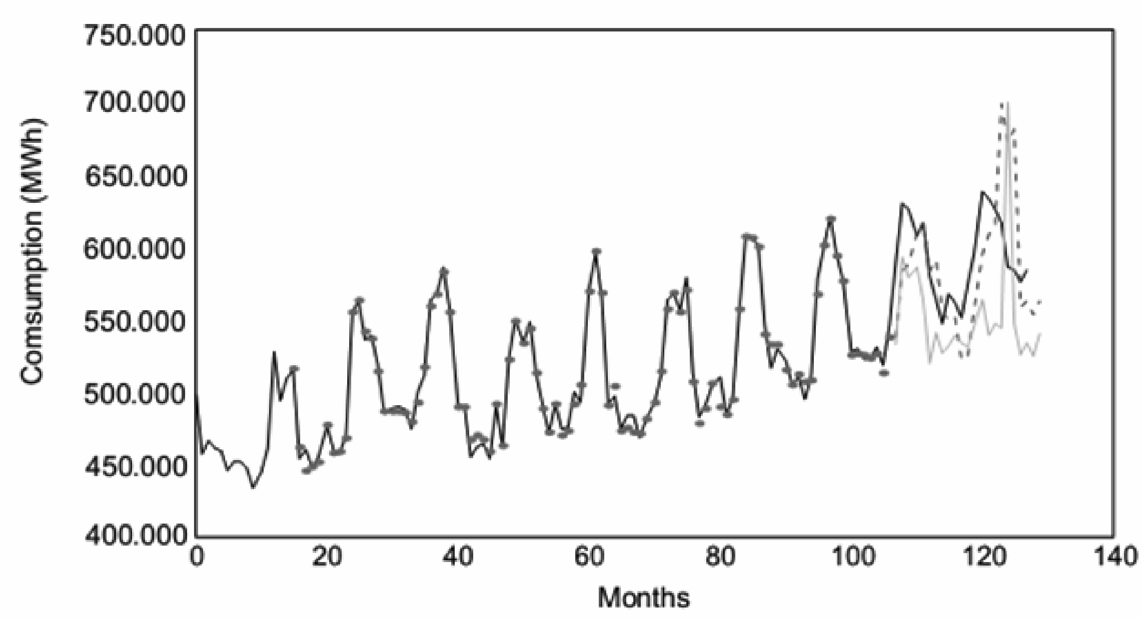

FIGURE 6: Network output versus the desired output for the experiments 3 and 4 training the readout to an error of 0.0005. Solid dark gray line: original series, gray points: output of the network for the training set, dashed line: network output without feedback (experiment 3), light gray line: network output with feedback (experiment 4).

The experiments 5 and 6 were performed to determine the accuracy of the long-term prediction (experiment 5 and 6). These experiments were done to predict the demand for the next 18 years using the same data as described for the previous experiments without feedback (experiment 5) and with feedback (experiment 6). The readout was trained until the convergence to the goal after 134 epochs considering an error of 0.0001. Figure 7 shows the results for these experiments.

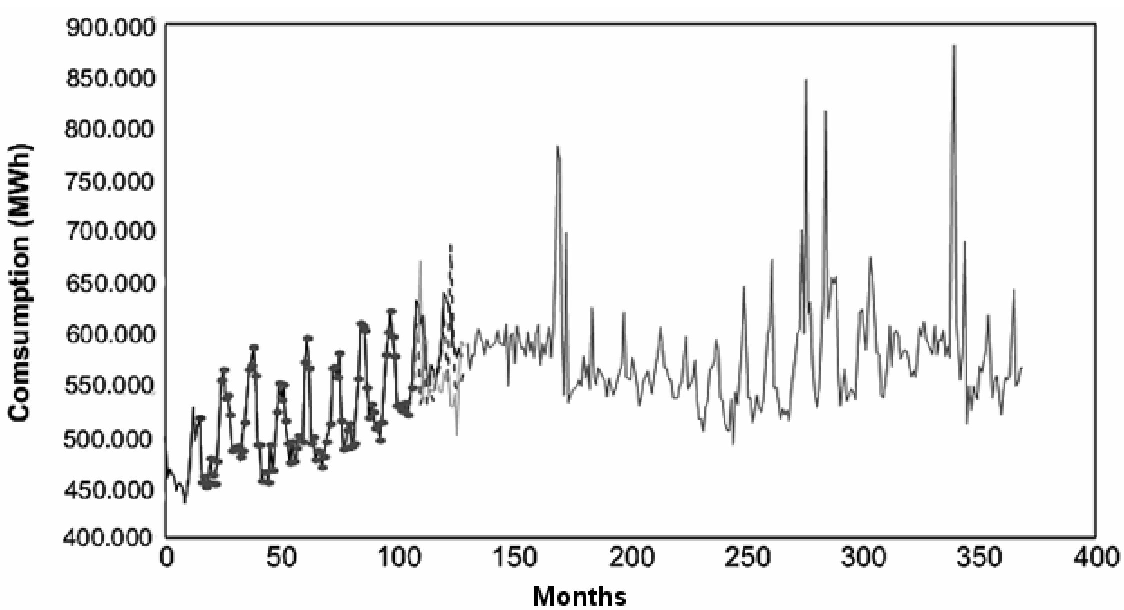

FIGURE 7: Results for the next 18 years with feedback, training the readout to an error of 0.0001. Solid dark gray line: original series, gray points: output of the network for the training set, dashed line: network output without feedback (experiment 5), light gray line: network output with feedback (experiment 6).

An additional experiment (experiment 7) was carried out to predict the demand for the next 20 years. For this experiment we used the same data sets as described for the experiments 1 e 2, but employing all the data contained in the time series for training. The readout was trained with feedback until the convergence to the goal after 280 epochs considering an error of 0.00001. Figure 8 shows a plot of the network output.

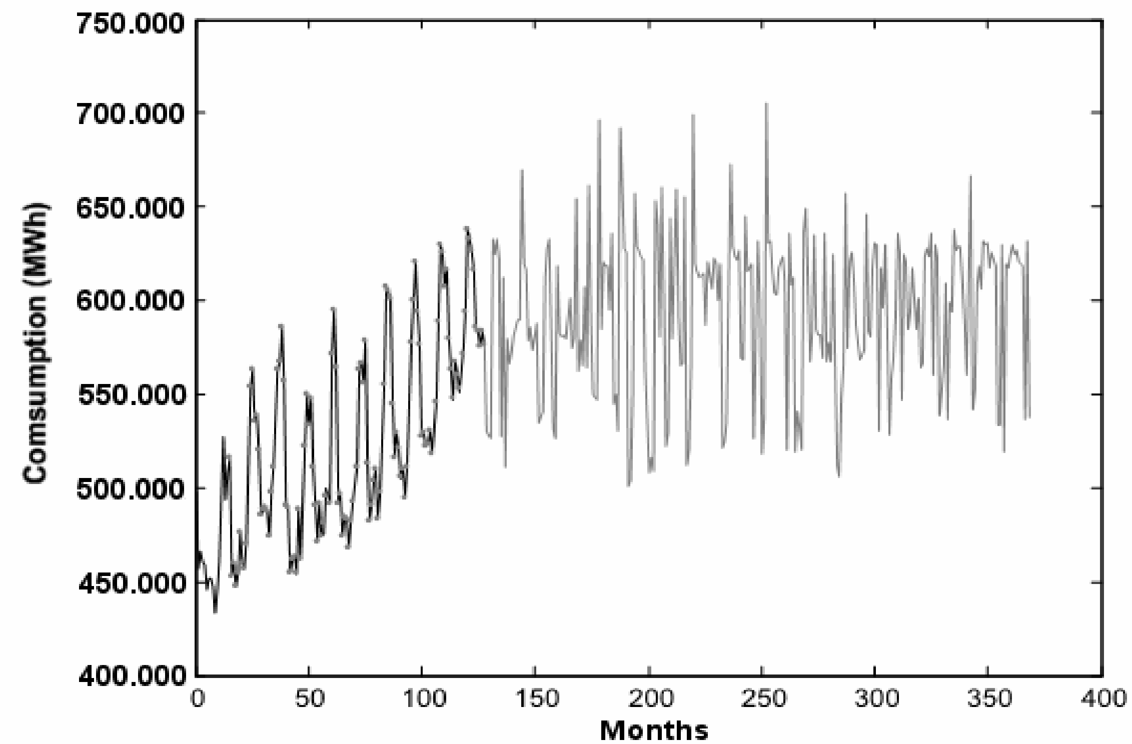

FIGURE 8: Results for the next 20 years with feedback, training the readout to an error of 0.00001. Black line: original series, gray line: output of the network.

The table 1 summarizes the results for the experiments with feedback and without feedback showing the MSE averaged for each experiment and the number of iterations reached. The MSE is not presented for the experiment 7, since the desired output is not available.

Experiment	MSE without feedback	MSE with feedback	MSE readout	N° iterations
1, 2	0.0120	0.0249	0.001	60
3, 4	0.0289	0.0502	0.0005	68
5, 6	0.0274	0.0413	0.0001	134
7	-	-	0.00001	280

Table 1: Comparison of results for the experiments 1-7.

Results shown in Table 1 show us that the model prediction reaches the error minimum in a small number of iterations. What is worth mentioning here is that no strategy of seasonal adjustment or preprocessing of data was achieved to extract non-correlated data out of the time series. Moreover, the data set comprises a small number of samples. Considering the predetermined error (MSE readout) to stop training the readout and the low number of iterations of training achieved by the readout, results of our prediction model are reasonable good.

The model with feedback results in a moderate performance, even for short periods of time. Feedback connections can cause oscillations. Since previous states are used in predictions of future states, these oscillations propagate and cause a degradation of performance.

Not surprisingly, the performance of the model for long periods of time is lower. RC methods tend to be sensitive to a small temporal range [34] which could be one of the reasons of this loss in performance. In addition, the lack of a seasonal adjustment can compromise the performance for the long term prediction since the monthly time series reveal strong seasonal components [2]. This probably produces the saturation of neurons that lose processing power.

5. CONCLUSION & FUTURE WORKS

Demand prediction is of great importance in the electricity supply industry. It is hard to find the right prediction method for a given application if not a prediction expert. This problem has been widely studied by researchers in different areas attempting to devise strategies to obtain accurate time series predictions. Recent works show that LSMs can be applied to the prediction of time series. The main advantage of the LSM is that it projects the input data in a high-dimensional space incorporating valuable information about recent inputs into input signal. This meaningful information allows that simple learning methods can be used to train the readout. As a result we can effectively apply the approach in temporal prediction.

In this paper we have presented an experimental investigation of an approach for the computation of time series prediction by employing LSMs in the modeling of a predictor in a case study for short-term and long-term electricity demand forecasting.

Four different modules composed the architecture of the LSM used in our approach: an input layer that is an excitatory analog input neuron used to feed data into the liquid, a pool of neurons of dimension $3\times3\times15$ (135) integrate-and-fire neurons formed the liquid, an exponential filter that decoded the liquid response, and a readout unit which computed an output obtained from the liquid neurons.

The approach was applied in seven different experiments to obtain the forecast of electric energy demand in state of Rio Grande do Sul (Brazil). The experiments evaluated short-term prediction with and without feedback and long-term prediction with feedback. The input vector of LSM was composed of a sequence of values whose size was defined by inspecting the seasonality of the time series. The information was presented to the LSM in short sequences $u(t)$ of 15 inputs, the current input at time step t and the last 14 inputs. The comparison of prediction performance with and without resetting the network reveals that the latter outperforms the former.

Each sequence was fed into the input layer; this sequence generates a signal of high dimensionality that encapsulates the dynamics of the liquid. Samples of the state of the liquid were taken in different instants of time forming a sequence of vectors, called state vector. The state vector representing the state of LSM for that sequence was decoded by the filter and projected onto the readout unit which predicted the value at the time step t+1 based on the input sequence $u(t)$. After that, the internal states of LSM were reset; a new sequence was presented to the LSM and so successively until all the information has been processed.

Results of this investigation are promising, considering the predetermined error (MSE readout) to stop training the readout, the low number of iterations of training reached by the readout and that no strategy of seasonal adjustment or preprocessing of data was achieved to extract non-correlated data out of the time series.

The results with feedback show a moderate performance even for short periods of time. Probably the oscillations generated by the feedback connections are propagated by the network resulting in a degradation of performance. The same fact occurs for long-term prediction for which the performance was still lower increasing the oscillations on the long timescale. In addition, RC methods tend to be sensitive to a small temporal range which could be another reason of this loss in performance.

The experiments show a reasonable performance of the LSM in predicting the “continuously” streams and that although our predictor model isn’t perfect it may be used for prediction of temporal time series problems and can serve as a powerful model for short-term and long-term prediction and pattern classification [35].

Many questions concerning the structure of the LSM are still open, due predominantly to the newness of the conception, which new research will have to address. Further research is encouraged to improve the performance of the LSM by investigating the size, topology and optimal parameters settings of the reservoir for prediction tasks. Also a larger data set is needed for a better comparison.

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