



A Survey on Classification of Types of Aphasia Using Artificial Neural Network

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Abstract— Aphasia is a language related disability. Aphasia patient cannot make correct use of language. Its ambiguous symptoms, inaccurate test items and diagnostic complexities make it an error prone decision making task. Various types of Aphasia include Broca, Wernicke, Anomic, Global, Conduction etc. Various tests are developed to test and classify types of Aphasia like BDAE, WAB, AAT, and IAB. Indian Aphasia Battery (IAB) test is specially modelled for Hindi language. In our day to day life we need to assign a label to any object by observing its various known features. Many problems in business, medicine, science and industry can be considered as classification problems. Statistical classification procedures assume certain assumptions to be satisfied. Neural networks are self-adaptive and data driven methods which means that they can adjust themselves to the input data without any external specification for the model. They are considered as universal functional approximators which mean that they are able to approximate any function with arbitrary accuracy. This paper reviews various techniques for automatic classification of aphasia giving special stress on artificial neural networks.

Keywords— Neural Networks, Speech Language Therapist (SLT), Aphasia, Neurolinguistics, Indian Aphasia Battery (IAB), Speech language Disorder

I. INTRODUCTION

Classification is a very common task. Everyone goes through decision making. The problems existing in business, science, industry, and medicine fields can be considered as the classification problems [1]. Classification can be performed by various numerous methods.

Discriminant analysis, a traditional statistical method of classification is built on the Bayesian decision theory. Here, an underlying probability model needs to be assumed to calculate the posterior probability and then on this probability result the classification decision is made. The problem with these models is that they work well only if the underlying assumptions are correctly made and satisfied.

Neural networks prove to be an important emerging tool for classification [1]. The advantage of neural networks lies in the various theoretical aspects. First, neural networks are data driven and self-adaptive methods. Second, they are able to adjust themselves to data without any explicit specification of functional or distributional form for the underlying model [2]. Also, it is universal functional approximator which means that it can approximate any function with great accuracy.

Neurolinguistics refers to the study of the relation of language and communication to different aspects of brain function, i.e. it explores how the brain understands and produces language and makes communication [10].

People with aphasia suffer in many ways. They make inappropriate combinations of words. They may pick wrong words or pronounce them incorrectly. They struggle to find words sometimes.

A. Various existing tests to detect Aphasia and its type:

- Boston Diagnostic Aphasia Examination (BDAE) test developed by Harold Goodglass and Edith Kaplan for English language.
- Western Aphasia Battery (WAB) test, developed by Showan and Kertesz in 1980 for English language.
- Aachen Aphasia Test (AAT) test, developed by Walter Huber in 1983 for German language.

Every language is unique in terms of its accent, pronunciation, vocabulary and structure. So, these tests are being adapted for various existing languages.

Indian Aphasia Battery (IAB) test is modelled for Hindi language.

This paper is organized as follows. In Section 2 overview of Neurolinguistics is presented followed by Aphasia, its types and tests for Aphasia in Section 3. Section 4 provides previous aphasia classification attempts and Section 5 explains Classification. Section 6 discusses comparison between Statistical classification and ANN based classification. In Section 7 we explored various feature selection techniques for supervised learning and in Section 8 a brief discussion on the stability of the feature selection algorithms is presented followed by Section 8 where validation of classifier is discussed and finally Section 9 presents the conclusion.

II. NEUROLINGUISTICS

Neurolinguistics comes in domain of Neuroscience in which study of relation between language and brain is done. It describes the way in which the communication is done and the process of producing and understanding language by the brain. Neuroscience covers Neurolinguistics, systemic, movement, sensory and cellular in its domain. It can be divided into two areas: language impairment and language acquisition and processing [9].

The scientific study of language and brain relationship came into existence in the last half of nineteenth century. A lot of study is being done by the scientists from the field of linguistics, psychology, speech pathology and neuroscience. Techniques from linguistics, psycholinguistics and other concepts from artificial intelligence, neuroanatomy being applied to solve traditional medical limitations.

A. *Views about the relationship between brain and language:*

- 1) Localism is the theory in which the specific locations and centres of the brain are identified for specific language functions. The localised higher functions in the brain are differentiated. Mostly these centres are given equal importance but some specific areas like prefrontal is considered super ordinate to the others [8].
- 2) Associationism keeps language functions in the connections between different areas of the brain for association. Associationism states that the higher functions in the brain are dependent on the connections existing between various centres of the cortex. Wernicke, Lichteim and Geschwind are the representatives of the view. Associationism is known as the classical and neoclassical view [9].
- 3) The view given by Luria is based on the theory that language functions are performed by functional systems of localized sub-functions. It is possible to reorganize these functional systems in the process of developing language because of their dynamic nature. The different sub-functions are considered as localized in different parts of the brain. The identified sub-functions are combined together in a way so that more complex functions can be created [9].
- 4) Marie, Head and Goldstein represented the Holistic theories called as cognitivism which consider that most of the language functions are handled by large parts of the brain working together. According to Holism the features which are a sign of a general cognitive loss include higher cognitive function, symbolic thinking, intelligence and aphasia.
- 5) Evolution based theories given by Jackson and Brown focuses on the relationship between the evolution of brain and language in various species, development of language in children and performance of these functions by adults. Evolution based theories emphasize on the structure of the brain discussing the role of all the layers in the process of language development and communication [8].

III. APHASIA

The neurobehavioral disorders are the conditions in which brain damage or dysfunction produces intellectual and behavioural change. Aphasia is a condition which affects the brain and restricts it from using the correct language.

A. *Main causes of Aphasia are listed below [11]:*

The main reason of Aphasia is damage to those parts of the brain which are particularly responsible for language functions. Other causes are:

- Stroke is the most common cause
- Brain tumour
- Severe injury on head
- Conditions that cause progressive brain and nervous system damage over time. These conditions are called Progressive neurological conditions

Aphasia may also occur with speech disorders like apraxia of speech, which again is the result of brain damage.

B. *Different types of aphasia:*

Aphasia is categorized into four main categories which are described below:

1) *Wernicke's Aphasia:*

Damage to the temporal lobe, side portion of the brain result in a fluent aphasia called Wernicke's aphasia. Patients suffering from Wernicke's Aphasia speak meaningless long sentences. They combine unnecessary words with the meaningless sentences leading to no sense of the phrase. For example, patient with problem may say, "You cold know that noodles pink coloured and that I went to get him from and take care of him like you like me before." It becomes difficult to infer the meaning of the phrase. Person suffering from Wernicke's aphasia have great difficulty in understanding speech and are unaware of their mistakes [11].

2) *Broca's Aphasia:*

Broca's aphasia is one of the non-fluent aphasia. Patient with Broca's aphasia suffer damage to the frontal lobe of the brain. Broca's aphasia patients frequently speak short phrases but are able to speak with great effort. They are observed omitting small helping verbs and prepositions like is, and the. A person suffering from the disease can say, "Walk to dog," which means, "I want to take the dog to a walk," or "book four table," instead of "There are four books lying on the table". They are often aware of their mistakes, difficulties and can become easily frustrated because they understand speech and language of others easily.

Some people can also have difficulty in repeating words and sentences in spite of being able to speak and understand the meaning of the words or sentences. Some other patients may have difficulty in naming the objects even after knowing the objects and use of that objects [11].

3) *Anomic aphasia:*

The patients with amnesic (anomic) aphasia find it difficult to use proper words in their sentences. But the speech is mostly fluent and with accurate meaning. Pauses can be observed in the speech due to their disability in retrieving proper words [2].

4) *Global Aphasia:*

It falls in non-fluent aphasia category. Left hemisphere lesion is responsible for this aphasia type. Receptive as well as expressive ability is affected much. People with this aphasia express themselves through facial expressions, gestures etc. [2].

C. Diagnosis of Aphasia:

Diagnosis of aphasia is done by the assessment of language capabilities of a person. It is done by SLT (speech and language therapist). Computer have played a very constructive role for the diagnosis of aphasia. Many applications are available to help SLTs.

1) *Communication assessment:*

Simple activities are carried out to evaluate the communication skills of a person. These include the tasks like:

- Naming words starting with particular letter
- Naming objects in surroundings
- Pronounce as many words as the person can
- Reading and writing

On the basis of these activities, SLTs evaluate following skills:

- Reading skills
- Writing skills
- Understanding of grammar
- Expression of words, sounds
- Fluency etc.

2) *Imaging scans:*

Images of brain are obtained by various techniques and detailed study of these images show how much brain is damaged. Most widely used techniques are listed below:

- CT (Computerised Tomography) scan
- MRI (Magnetic Resonance Imaging) scan
- PET (Positron Emission Tomography) scan

IV. APHASIA CLASSIFICATION APPROACHES

A. Aphasia Test Score based approaches:

A web based classification model is developed for Aphasia classification in [3]. Aachen Aphasia Test (AAT) is used to generate database. This test is for German language. Two classifier models are used to classify Aphasia in four types. Commercial Software Data Engine is used to create Multilayer Perceptron network. The first classifier is based on spontaneous speech subtest of AAT. Details of this are as:

Network: Multilayer Perceptron

Inputs: 6 Spontaneous speech test scores.

Neurons: 6-5-4 for input, hidden and output layers respectively with activation functions of linear, sigmoid and sigmoid types

Software: Data Engine

Learning method: Back Propagation method is used in combination with momentum

Second model was used for selected features. These features were selected by Feature Selector software out of all 30 features. Details of this are as:

Network: Multilayer Perceptron

Inputs: 4 Test scores which include - melody of speech, grammar used, repetition efficiency and reading aloud

Neurons: 4-5-4 for input, hidden and output layers respectively for linear, sigmoid and sigmoid activation functions

Learning method: Back Propagation method is used in combination with momentum

Software: Data Engine package with Feature Selector Software

In this research Aphasia is divided into three types namely a grammatic, semantic and phonologic [25]. They use picnic picture description test of WAB for elicitation. This test is for English language. Information Gain (IG) value is calculated to measure the discriminability power of each feature. 40 high IG value features are used for classification. Naïve Bayes Multinomial model is used as classifier.

B. Speech recognition based approaches:

In this research speech of three groups are used: semantic dementia (SD), progressive non fluent aphasia (PNFA), and healthy controls [27]. These speeches are in English language. They extracted total 58 features from each speech by using Stanford Parser, Stanford POS Tagger etc. For feature selection a two sample t-test on each is conducted. All features which are significant at $p \leq .05$ are used for classification. Three machine learning classifier from WEKA machine learning toolkit are used. These are: Naive Bayes classifier based on Bayes' theorem, logistic regression, and Support vector machines.

This paper used speech of three groups: progressive non fluent aphasia (PNFA), semantics dementia (SD) and logopenic progressive aphasia (LPA) [26]. Speech samples of each are recorded. Analysis of this speech is done to extract seven type of features: part of speech features, complexity features, CFG features, fluency features, psycholinguistic features, vocabulary richness features, and acoustic features.

For feature selection it considers four scenarios:

1. Given audio files only
2. Given basic transcription only means no audio
3. Given fully segmented transcripts
4. Given audio and fully segmented transcripts

For each scenario researcher rank features by its chi- square value. Top 10 features from each group are selected and used as input to classifier model. SVM is used for classification.

C. Word recognition based approach:

In this work author designed a speaker independent system that can be used for non-continuous small vocabulary speech [28]. Database is single word response to short form of the Boston Naming Test (BNT). The "AT & T Speech Mash up" speech recognition system is used to generate 403 samples.

Each of 403 sounds is played into one of the three speech recognition grammars and responses are recorded as accepted or rejected.

These 403 samples are then judged for correctness by two experienced clinicians.

V. CLASSIFICATION

Classification and decision making are important task in day to day activities. Classification can be defined as forecasting the output based on current available knowledge and past experiences of the things [2]. Formally, classification is assigning an object to predefined class by observing features of that object [1]. Classification is the problem observed in many areas like health, medicine, industry, science, engineering and banking. Classification is applied in Preliminary diagnosis and early medication in medicine, loan sanctioning to a person in bank, predicting the output of any machine in industry.

Main goals of a classification technique are [2]:

- It should cover a wide range of problems
- Can be applied to all the datasets small and large with variable features
- Can be implemented in a feasible way
- Should produce satisfied and justified results
- Should have better performance when compared to human decision making

Problem in classification model based on a particular classification techniques [2]:

- Easy to understand: The method needs to be easy to understand for its implementation, working in order to be free of errors [2].
- Training or learning time: model should be able to learn the rules easily and instantly.
- Speed: speed refers to the time taken to produce the result after input of the data. It must be minimized.
- Accuracy: Accuracy is divided into two types, training accuracy at the time of model training and testing accuracy at the time of testing. For a system to produce desired output, the testing accuracy is must.

A. Basic classification approaches:

1) Multivariate discriminant analysis (MDA):

MDA approach works on a random sample of observations which are defined by a set of variables. It then generates a discriminant function and calculates certain characteristics used to classify the resultant observations into one of the groups of dependent variables or population which in turn minimizes the misclassification cost. MDA considers that all variables are independent of each other and are normally distributed. The linear classifier requires structure of independent variable covariance matrices similar in all the groups of dependent variables. Fisher's procedure makes a discriminant function to maximize the inter groups and intra groups variances ratio. The approach produces a linear function which is able to partition the variable space into two. Bayes' theorem helps in obtaining the posterior probability of membership in the predicted group when the discriminant score is given. Situations are considered deviated from this condition when the observations from every group make separated regions in the variable space. The high error rate of discriminant functions for the training and holdout sample depends on the number of separated regions present in each group.

2) *Kth-Nearest Neighbour:*

kNN is the parameter or distribution-free approach [15]. Quantitative variables are the key features to classify the observations into numerous groups [18]. It does not need any functional form and logistic regression as in Discriminant Analysis and also relaxes the normality assumption. The Mahalanobis distance defines the distance(x, y) between observations x and y. An observation is classified under the group which consists of its maximum number of kth-nearest neighbors. Dividing the variable space into number of decision regions not more than total number of observations helps in calculating the sample distribution approximation.

3) *Decision Trees:*

These are very popular and important approach for classification in various data mining applications and for decision making. A decision tree is a known as directed tree consisting of one root node without any incoming edges and all child (decision) nodes have exactly one input edge [17]. While the decision tree is in the training stage, each and every internal child node divides the input instance space into two or more parts for optimizing the classifier performance. A decision rule is formed using all the paths reaching leaf node from root for determining the class of the new instance.

ID3 and C4.5 are popular Decision Tree algorithms. C4.5 is improved version of ID3. The new features in C4.5 decision tree algorithm include: (1) discrete and continuous attributes can be handled; (2) employ information gain ratio; (3) incomplete training data with missing values can be handled; (4) To avoid over-fitting pruning can be done during the construction of trees.

Traditional decision tree approaches have many challenges.

- Creation of a decision tree with the large volume of dataset can be very time consuming
- New computing approach need to be applied for the clusters.
- The optimized strategy for data distribution to be used to localize the appropriate data for building one node
- Minimizing communication cost

4) *Support Vector Machines:*

Vapnik and his colleagues introduced Support Vector Machines to solve the pattern classification and regression problems [16]. SVM divide n dimensional plane into two distinct sets. It builds a boundary between two sets which is known as hyper plane. This separating hyper plane increases the margin between the given two data sets till the maximum value. Couple of parallel hyper-planes is further created on each side of the main separating hyper-plane for the purpose of calculating the required margin. It is possible to achieve a significant separation by the hyper-plane which possesses the maximum distance from the neighbouring data points in both the classes. The generalization error of classifier is less when the margin is large. This hyper plane is calculated with the help of support-vectors and margins.

VI. STATISTICAL CLASSIFICATION VERSUS ARTIFICIAL NEURAL NETWORK CLASSIFICATION

Traditional statistical classification procedures are applied only under certain conditions. It assumes a probability model to calculate posterior probability which is used to make classification decision. The limitation of statistical model is that it performs well only if certain assumptions are satisfied. User need to know data properties and model capabilities before applying the model [1].

Neural networks have ability to model complex functions. These are fault tolerant and self adaptive.

Neural networks have following highlighted advantages:

- These are data driven self-adaptive so there is no need to follow any distributional form
- Neural network are capable of approximating any function with arbitrary
- They are nonlinear model so are capable to model any real world problem
- Neural networks are capable of estimating the posterior probability which is the basis of classification rule

Neural networks have been used in many classification problems like medical diagnosis [23], handwriting recognition [24], bankruptcy prediction [22], and speech recognition [7].

Direct comparison between neural network and statistical methods is not an easy task because:

- Neural network are nonlinear whereas statistical methods are linear
- Neural networks are model free while statistical methods are model based

Michie [21] performed very rigorous comparisons between artificial neural network and statistical classifiers in Stat Log project. In this project he made comparison between neural networks, statistical classifiers and machine learning with 23 methods by using around 20 actual data sets. He concluded that neural network gave better performance in many problems. Neural networks are also compared with decision trees [11], discriminant analysis [12], k-nearest-neighbor [13], and linear programming method [14].

TABLE I. COMPARISON OF VARIOUS CLASSIFICATION TECHNIQUES

Techniques	Advantages	Disadvantages
MDA	<ul style="list-style-type: none"> ○ Consists of Multiple dependent variables. ○ Reduced error rates ○ Helps in easier interpretation of inter-group differences 	<ul style="list-style-type: none"> ○ Each discriminant function show equal variances in each group. ○ The relationships between variables are linear in all groups

Techniques	Advantages	Disadvantages
	<ul style="list-style-type: none"> Each discriminant function leads to something different and unique. 	<ul style="list-style-type: none"> Discriminant analysis is extremely sensitive to outliers.
Decision Tree	<ul style="list-style-type: none"> It show possible course of action not considered earlier. Result decisions improved by the numerical values. It forces management to take account of risks. 	<ul style="list-style-type: none"> Preparing decision tree is time consuming and complex. require high expertise and experience Due to complexity cost is high
kNN	<ul style="list-style-type: none"> Robust to noisy training data Effective for large datasets Fast training speed 	<ul style="list-style-type: none"> Need to determine value of parameter k. Doubt in type of distance and attributes to be used Computation cost high Memory limitations
SVM	<ul style="list-style-type: none"> It is defined by a convex optimization for which many efficient methods are there. 	<ul style="list-style-type: none"> Binary Classifier Computationally expensive Runs slow
ANN	<ul style="list-style-type: none"> Can adapt unknown situations Easily model complex functions Universal approximators 	<ul style="list-style-type: none"> Network is complex Design issues like number of nodes, activation function, weight adjusting, etc.

VII. FEATURE SELECTION TECHNIQUES

Dimensionality of data is growing exponentially which has become a challenge to feature selection algorithms. Main problems are [20]:

- High dimensionality
- Large storage requirement
- High computational cost

Feature selection is defined as a technique to reduce dimensionality which aims to select only small subset of features by excluding redundant, noisy and irrelevant features. Feature selection focuses on high learning, better model interpretability and lower computation [19]. Feature selection can be categorized into three types: Filter, Wrapper, and Embedded. Embedded techniques are specific to a model. Wrappers work on the basis of a search algorithm to search through the space of possible features. Wrappers have a risk of over fitting to the model and are computationally expensive. Filters are like Wrappers in the search approach and a simpler filter is evaluated instead of a filter against a model. Basis of filter metrics are:

- Correlation and mutual information
- Class separability
- Error probability
- Inter class distance and entropy etc.

A. Characteristics of Feature Selection Algorithms [19]

The important characteristics of feature selection algorithms are listed below:

- 1) *Search Organization*: The algorithm has knowledge about previously visited states. It uses this information. When it needs to visit a non-visited state then it use heuristic knowledge about it.
- 2) *Successor generation*: It is a mechanism by which successor candidates of the current hypothesis are proposed. To generate a successor for each state the operators used are Forward, Backward, Compound, Weighting, and Random.
- 3) *Evaluation measure*: Function by which successor candidates are evaluated, allows comparing different hypothesis to guide the search process.

TABLE II. COMPARISON OF FEATURE SELECTION MODELS

Model	Computational Speed	Dependency on Classifier	Computational Complexity	Interaction with Classifier
Filter univariate	Fast	Independent	Better than Wrapper methods	No
Filter multivariate	Slower than univariate	Independent	Better than Wrapper methods	No
Wrapper deterministic	Less intensive than randomized methods	Dependent	Poorer than Filter and Embedded methods	Yes
Wrapper randomized	Intensive	Dependent	Poorer than Filter and Embedded methods	Yes
Embedded	Better than filter and wrapper methods	Dependent	Better than Wrapper methods	Yes

VIII. VALIDATION OF CLASSIFIER MODEL

It is important to choose validation method for the chosen classifier. Cross-validation is one of the validation methods which split the input data into training and testing sets and then the test set is validated against the training set to check whether the classifier is able to reproduce the desired output. The simplest method of cross validation is the 2-fold cross-validation. It randomly splits the data into training and test sets. The extension of the 2-fold cross-validation is the K-fold cross-validation where the data is split into K subsets randomly. For training purpose K-1 subsets are selected and then the remaining subset is used for testing. The process is repeated till the point when all the subsets are used for testing purpose. Leave-one out cross-validation is a variation of the K-fold cross validation. In this scenario only one sample is used for testing. Other samples are used to train the model. This process is repeated for next sample unless all samples are tested. For model selection the training set can be further split into training and validation sets. The cross-validation methods may lead to over estimating the model performance.

IX. CONCLUSION

Aphasia classification is a well researched topic. Even though there are many other topics that have been investigated in the literature, but this review paper has covered the most important aspects and concepts of neural networks which can be used in solving Aphasia classification problems. Neural networks can be projected as best pick in replacement for other classifiers for most of the existing practical classification problems. Neural networks have been intensively studied to make its use in performing classification and other similar tasks. Neural networks is a practical decision making tool and need to be evaluated and compared systematically with other new and existing traditional classifiers. Several authors have focused on the lack of the rigorous comparisons between neural network and other classifier. A lot of work has been done for Aphasic patients with English background. But a lot more work is to be done for Hindi language. The broad nature of the neural network for Aphasia classification research is going to generate more fruitful desired results in the future.

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