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DESIGN AND DEVELOPMENT OF HAND-HELD SMART SPIROMETER

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ABSTRACT

Developing countries like India are progressing in urbanization, demographics, and economic profile but on the contrary, plagued with extreme mortality morbidity and rate. The absence of accurate clinical decision support systems (CDSS), poor methodologies for diagnosis at primary health care centers has lead to under diagnosis of various diseases. Though Machine Learning (ML) is attracting widespread attention due to its huge potential and promising results, yet there has been very lean research in ML based medical diagnosis. Knowing how to take accurate decision is an important skill, when machine exhibit this we say they are intelligent. The purpose of this paper is to show how intelligent decisions can be made using CDSS for Chronic Obstructive Pulmonary Disease (COPD), which is one of the fatal epidemics. A systematic analysis of various ML algorithms spanning from neural network (NN) to support vector machine (SVM) is carried out. The result shows 98% accuracy is achieved using random forest classifer when compared with real-time lab diagnosis. We infer that ML based CDSS for COPD will take diagnosis to the unreachable mass, avoids frequent visit to the hospital and will be a game changer in Indian rural health care.

Keywords: Chronic Obstructive Pulmonary Disease, Intelligent Decision Support System, Clinical Decision Support System, Machine Learning, Random Forest Classification.

I. INTRODUCTION

Eugen sandow once said" Health is a divine gift, and the care of the body is a sacred duty, to neglect which is to sin". COPD is one of the inflammatory lung disease that is characterized by permanent airflow blockage to the lungs. This disease is widely under rated and under-diagnosed, even though it is death causing and irreversible lung disease [1]. It is estimated that 251 million people around the world are suffering from COPD [2] which is 4th leading cause of deaths and estimated to escalate to 3rd position by 2030. India is a major contributor in mortality due to COPD i.e., 102.3/100000, approximately 70lakhs Disability Adjusted Life Years (DALYs) and 27,756,000 DALYs around the world. If this trend continues unabated, COPD has potential to overwhelm health systems and state economies [3].

COPD throws challenges not only in terms of unreliable epidemiology but also in accurately diagnosing the disease and maintaining the patient record. The main reasons for under diagnosis of the

disease are Lack of awareness, its symptoms which surface at severe stage of the disease. Even when a person with symptoms does consult a general practitioner, It is more likely to be under diagnosed. Spirometers are not usually present in every health care center and diagnosis of the disease extensively based on symptom. Usage of inhalation devices for diagnosis and management of COPD is usually considered at severe stage and such prescription is a fear factor in rural scenario. Moreover majority of rural and semi urban population are dependent on alternative medicine practitioners and faith-healers; who frequently prescribe toxic and harmful agents that may contain steroids. Therefore there is a need of an accurate decision support system installed at every primary health care centers.

Spirometer is a form of Ventilometer or Spiro/breath analyzer and is generally used for measuring the bronchial activity and breathing capacity of lungs. Various types of spirometers are Body plethysmo graph, Pneumotachometer, Incentive Spirometer, Wind mill type Spirometer. This spirometer generally measure parameters such as Function Residual Capacity (FRC), Peak Expiratory Flow (PEF). These spirometers are generally large in size and very inaccurate because COPD not only depends on breathing capacity but various external factors.

To overcome this issues we developed a portable, hand held, intelligent decision support system which uses machine learning approach for highly accurate prediction of disease. Various machine learning algorithms such as logistic regression, k-nearest neighbors, decision tree classifier, random forest classification, support vector machine, kernel based support vector machine and naïve bayes were tested for accuracy of disease prediction. Highest accuracy of 98 % has been achieved with Random Forest classification algorithm when compared to other algorithms.

This IDSS can be used to know the symptoms of COPD and to make sure people get the right treatment, and helps diagnose and manage respiratory disorders. Large e-spirometers used in the hospitals are quite expensive, massive, complex and therefore not affordable and used in many health care centers especially un-urbanized areas where the hospitals lack sophisticated equipments . So this system would be very beneficial to enable fast detection regardless of time and place.

II.LITERATURE SURVEY

COPD is an epidemic, chronic and non-communicable disease. It challenges health care system with continuous burden and constant “incidence rate”. Factually, it is still an unrecognized epidemic in the developing part of world like India. The data about this disease from India is a small sample of millions of patients. This scenario will lead to increased economic burden, mortality and morbidity rates.

COPD being chronic and progressive, ruins families with middle and low income both financially and morally. Factually, the estimate of financial requirement per patient has risen drastically with an exponential increase in cost of medicine, hospitalization and other treatment modalities.

There are various factors for development of COPD, smoking and use of non- conventional form of tobacco being the most important risk factor. Exposure to smoke due to burning of woods, crop residues, animal dung,

poor ventilation in cooking areas and exposure to polluted gases, dusts also contribute to prevalence of COPD. In rare scenarios, non smoking population who lack alpha-1 antitrypsin (protein) can develop the disease. Prevalence of COPD was recorded to be around 3.2% in females and 5% in males. Smokers have 300% more chances of having COPD in comparison with non-smokers. Bidi and hookah smokers were at a greater risk of developing COPD (8.2%) than people who smoke cigarette (5.9%)[4]. Exposure to cooking fuels such as LPG and kerosene also led to development of COPD and it was recorded to be 2% and 5% respectively.

COPD can be broadly classified as Chronic bronchitis and Emphysema. Patients with chronic bronchitis suffer with long term cough consisting of mucus whereas damage of lungs in due course of time is caused in the case of emphysema. Most of the effected people have a combination of chronic bronchitis and emphysema. Emphysema is a chronic lung condition in which alveoli may be destroyed or narrowed or collapsed or stretched or over-inflated. This may lead to breathlessness and decreased lung capacity. Permanent holes or complete damage of lung tissues is caused due to damage of air sacs. Chronic bronchitis is a long-term inflammation of the bronchi which result in disability, breathing problems, cough and frequent infections.

COPD symptoms include chest tightness, fatigue or inability to exercise, wheezing or a chronic cough, shortness of breath, and loss of muscle, or weight loss. Conventional methodology used for detection of COPD is to undergo the following tests.

- A chest X-ray is used to identify emphysema which is key factor for the development of COPD.
- Arterial blood gas analysis measures how efficiently your lungs are able to remove CO2 and bring O2 into your blood.
- Pulmonary function tests (PFTs) are conducted for measuring the inhalation and exhalation capacity of your lungs.
- CT scan helps in determining whether a surgery is required to treat you for COPD or not.

Treatment consists of bronchodilators and self care (quitting smoking, Physical exercise and diaphragmatic breathing). Oral steroids and rescue inhalers help in minimizing the further damage and also to control symptoms. This diagnosis is financial burden to a middle or low income individual. Also a failure to asses and recognize the disease extremity and the occurrence of respiratory dis-functionality is common due to lack of equipment and proper methodologies. Chest radiography is more commonly used to continuously monitor the patient, which is misrepresentation of the COPD stages. The precise finding of hyper inflation and early stages of emphysema are often times missed. To overcome the above drawbacks the use of electronic clinical decision support system is required. A CDSS is an electronic or internet application that analyses data to help primary healthcare practitioners. Vowing to the progress made in artificial intelligence (AI), scientists suggested to exponentially increase the usage of AI tools for managing non-quantitative, knowledge-rich, weakly structured decision domains (Simon, 1987). This resulted in development of intelligent decision support systems (IDSS). Use of machine learning (ML) allows decision support system to obtain new patterns or to adapt to the changing environment or user. Through many studies, we can infer that CDSS has reduced unnecessary/wrong prescription of drugs and medication errors. This proves that more precise medication will be ensured. For example in Korea, the research shows that there has been a change in prescribed medicine on post and pre application of CDSS [5]. Decrease in medication errors was achieved with the help of CDSS.

Sandhya Joshi et al.(2013)[6] compared SVM based on particle swarm optimization (PSO-SVM) and Principle Component Analysis- Grid- Support Vector Machine (PCA-Grid-SVM) and claims to achieve 96.7% accuracy with PSO- SVM.

Jensen et al. (2012)[7] investigated prediction of exacerbations with the help of physiological data. Hundred and eleven patients were monitored over a period of 120 days. Performances of DSS in predicting exacerbations are in terms of sensitivity and specificity (70% and 95%).

D.Yanez et al.(2012)[8] use heuristic based approach to investigate wether prediction of exacerbation is possible with the increase in respiratory frequency. 89 patients were monitored for continuous 3 months. Sensitivity of 72% and specificity of 77% were achieved.

Fernandez-Granero et al.(2014) [9] predicted exacerbations with the help of COPD related symptoms via home telemonitoring using probabilistic neural network. For a period of 6 months, 16 COPD affected patients were monitored and performances of DSS was evaluated in terms of sensitivity (94.34%), accuracy (8.3%) and specificity(80.5%,).

Mohktar et al. (2015)[10] used CART classifier for exacerbation prediction with the help of home telemonitoring.21 patients were examined. Performance parameters such as accuracy (71.8%), sensitivity (80.4%), and specificity (61.1%) were achieved.

Sujatha C manoharan et al. (2008)[11] compares two artificial neural networks for classification of spirometer data. It is examined that Radial Basis Function Network (RBF) has an edge over back propagation neural network in terms of accuracy, specificity and sensitivity. RBF outperforms BPF in all the three aspects.

The major drawback of all current approaches is use of very small training datasets. Machine learning methods for modelling of small datasets remain scarce. As complexity of problem is very high, huge datasets are required. To overcome this drawback various data augmentation methods or K-fold cross validation and bootstrap method can be used.

As the wrong prediction of the result might be catastrophic and lead to death of the patient, high accuracy in prediction of results is demanded. The above approaches show less accuracy, specificity and sensitivity which is not acceptable.

III. PROPOSED MODEL

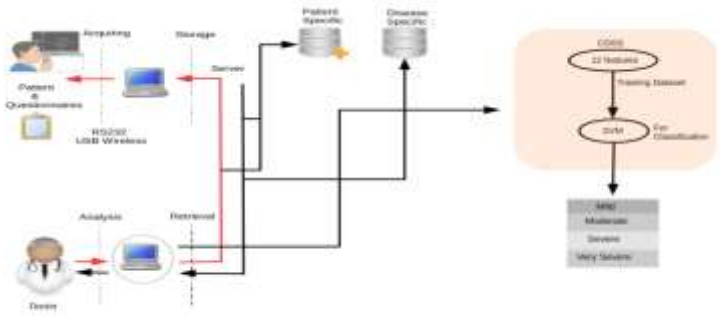

Fig 1: Proposed Architecture of Intelligent Decision Support System.

People over the age of 35 years, suffering from chronic cough, frequent winter colds, shortness of breath or any symptoms of the disease should consider COPD test. CDSS shown in figure 1 is then used to confirm whether the patient is COPD positive or negative. Diagnosis starts with a questionnaire consisting of questions such as smoking status, Frequency of exposure to alternate smokes such as biofuel, smoke due to kerosene etc. How old is the patient? What is your Body Mass Index (BMI)? Do you cough only in winters? Do you suffer sputum production in spite of dry nose? How often do you have any wheezing? The questionnaire is followed by spirometry test as shown in fig 1. It is used to measure the lung capacity in terms of Forced expiratory volume in one second and Forced Vital Capacity, which is greatest/maximum volume of air breathed by the patient out in a single breath. A person having FEV1/FVC ratio less than 70% along with symptoms of COPD defines a person as COPD positive. To calculate FEV1 and FVC a barometric pressure sensor implanted in funnel like structure is used. Raspberry pi is used as computational hardware and python is used for programming.

IV.RESULTS

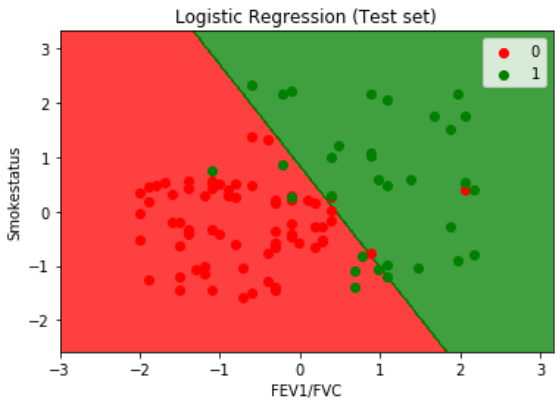

Fig 2: Logistic Regression

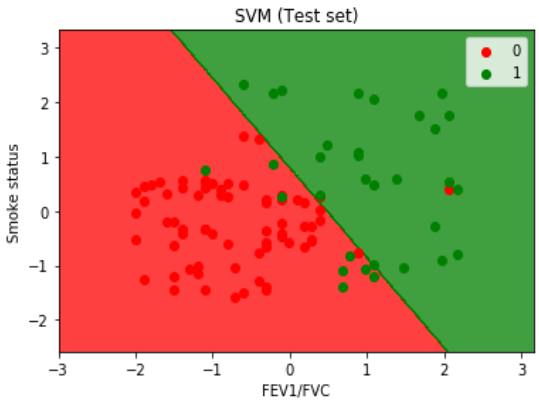

Fig 3: Support Vector Machine (SVM)

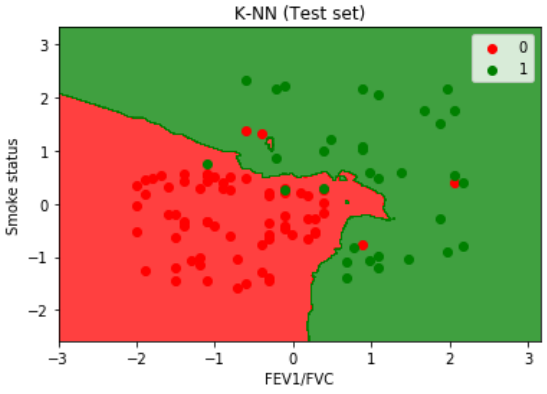

Fig 4: K-nearest

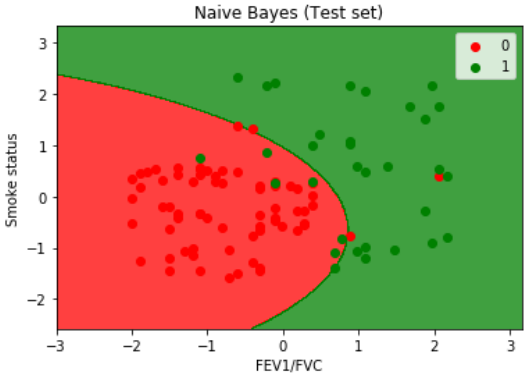

Fig 5: Navie Bayes

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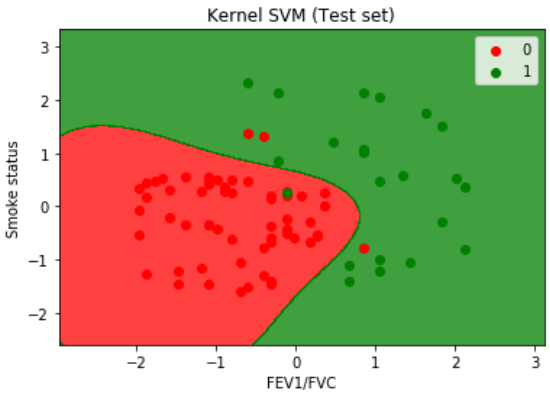

Fig 6: Kernel SVM

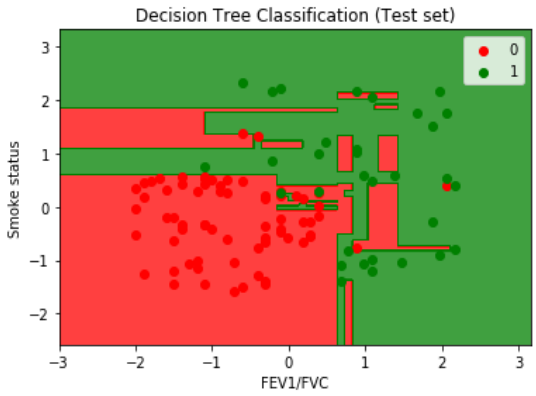

Fig 7: Decision Tree Classifier

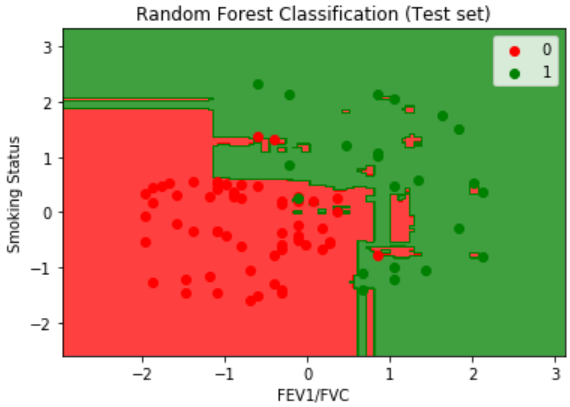

Fig 8: Random Forest Classification

Various Machine learning Algorithms such as Linear Regression, K-nearest neighbors, Naïve Bayes, Linear SVM, Kernel SVM, Decision Tree and Random Forest Classifier were analyzed for differentiation patients with COPD and non-COPD. The results are shown in Fig 2,3,4,5,6,7,8. Highest accuracy of 98% was achieved with random forest classifier.

V.CONCLUSION

While COPD is 4th leading death causing disease in the world, early detection is mandatory. Keeping various parameters such as portability, accessibility, and financial burden, we developed a low cost CDSS which can detect COPD at an early stage. This clinical decision support system collects biometric data and spirometeric data and classifies the patient using sophisticated Machine Learning techniques with the help of previous patient records and clinical expertise. We were able to achieve accuracy of 98% sing Random forest classification. Modularity helps this CDSS in adapting to various conditions. This helps in efficient telemonitoring and teletraining of COPD patients.

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