An Intelligent System for Diagnosis of Various Conditions of Glaucoma Disease in the Field of Ophthalmology

Ph.D. Synopsis

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Index

I. Title of the Thesis and Abstract :

Title of the Thesis: "An Intelligent System for Diagnosis of Various Conditions of Glaucoma Disease in the Field of Ophthalmology"

Abstract:

Decision support system in medicine is a peculiar form of clinical data processing coming from a range of clinical as well as atomized systems. However, it is more complicated in medicine than in other areas, because of medical terms, semantic relations and amount of data. Reaching a full proof diagnosis in Ophthalmology, is never an easy job for a clinician. There are number of examinations performed using various diagnostic instruments, in order to diagnose the problem from the symptoms described by the patient. Result of each examination needed to be inferred separately, because of the variation in representations and their significances. For accurate diagnosis, the results of number of examinations are to be inferred in a contextual conjunction. This is again a complicated task forming the diagnosis.

Glaucoma, an eye diseases is prevailing in aging population. It causes an irreversible loss of vision. There is a distinct need of Computer aided solutions for diagnosis purposes. [24] The rising concern for the treatment of this disease is increasing looking at the propagation of glaucoma cases in past few recent years. It is majorly widespread in urban aging population. According to an estimation, 79 million individuals all over the world would be affected by glaucoma by year 2020. [34] [15] Within a decade, the estimation shows a 33% increase in the number of people affected by glaucoma. [36] Thus, screening for glaucoma is crucial, owing to the nature, for the early detection and enabling effective treatment in early stages to prevent permanent blindness. [24]

According to Glaucoma society of India, glaucoma is the second leading cause of blindness in India. The major challenge posed by Indian population is the number of people getting affected by glaucoma. At present, 12 million people in India are affected by glaucoma which is expected to increase to 16 million by 2020 [36]. The number of patients per ophthalmologist is around 2 to 3 lakhs in India. Thus apart from cost, lack of manpower in terms of skilled technicians poses major challenge in such scenarios.

Diagnosis of glaucoma is dependent on various findings such as IOP (if IOP > 21 mm Hg [17], it is considered as a suspicious case for glaucoma), optical nerve cupping and visual field loss. Detection and diagnosis of Glaucoma is performed through various tests such as Tonometry, Ophthalmoscopy, Perimetry, OCT, Gonioscopy and Pachymetry. [10]

Artificial neural networks are finding many uses in the medical diagnosis application. Artificial neural networks provide a powerful tool to analyze and model complex clinical data for a wide range of medical applications. Most applications of artificial neural networks to medicine are classification problems; that is, the task is on the basis of the measured features to assign the patient to one of a small set of classes. [35] An artificial neural network a part of artificial intelligence, with its ability to approximate any nonlinear transformation is a good tool for approximation and classification problems. [40][25][4] Multilayer perceptron (MLP), a feed-forward, back-propagation network, is the most frequently used ANN technique in glaucoma research. [37]

The primary focus of this research is to develop an intelligent diagnostic system for Glaucoma- an eye related disease, from the data obtained through clinician by various examination devices or equipment used in ophthalmology. These is used as training set to multi-classifier, developed using hybridization of various techniques of Artificial Intelligence. The classification is done by a hybrid approach using Artificial Neural Network, Naïve Bayes Algorithms and Decision Tree Algorithms. A design/development of a new technique or algorithm is required for such diagnosis and it is tested for its efficacy. Using the algorithms and techniques of Neural Network, Naïve Bayes Algorithm and Decision Tree based classifiers, the proposed hybrid technique is anticipated to intelligently analyze and perform diagnosis for patient's visionary predicaments, thus lessening the intervention of medical practitioners in terms of decision making.

II. Brief Description on the State of the Art of the Research topic :

The last few decades have seen a proliferation of intelligent systems for diagnosis, advising and related applications. Intelligent systems for diagnosis have been used in a variety of domains: plant disease diagnosis, crop management problem diagnosis, credit evaluation and authorization, financial evaluation, identification of software and hardware problems and integrated circuit failures, troubleshooting of electrical, mechanical and electronic equipment,

medical diagnosis, fault-detection in nuclear power systems, oil exploration, prospecting, seismic studies, etc. Despite the great variety of approaches and technologies used in the design of such systems, they all address the same pattern classification problem: the task of assigning a given input (e.g., a pattern, image, set of observations, etc.) to some category (or class). Diagnosis systems classify the observed symptoms as being caused by some specific problem (diagnosis class) while advising systems perform such a classification and suggest corrective remedies. [9][12][16][38].

The logical thinking of medical practitioner involves a lot of subjective decision making and its complexity makes traditional quantitative approaches of analysis inappropriate. The computer based diagnostic tools and knowledge base certainly helps for early diagnosis of diseases. The intelligent decision making systems can appropriately handle both the uncertainty and imprecision. [41] AI can definitely assist clinicians to make better clinical decisions or it can replace human judgment in certain functional areas of healthcare. [18] Guided by relevant questions pertaining to various clinical parameters, a powerful AI techniques can reveal hidden information from the massive quantity of data, which plays a key role in assisting clinical decision making.[26][19][11].

The application of machine learning models [27] on human disease diagnosis aids medical experts based on the symptoms at an early stage, even though some diseases exhibit similar symptoms. Many intelligent system have been developed for the purpose of enhancing health-care and provide a better health care facilities, reduce cost and etc. As express by many studies [28][29][1] (such as Mahabala et al., 1992; Manickam and Abidi, 1999; Alexopoulos et al., 1999; Zelic et al., 1999; Ruseckaite, 1999; Bourlas et al., 1999), intelligent system was developed to assist users (particularly doctors and patients) and provide early diagnosis and prediction to prevent serious illness.[45][39][5]

Fujita et al. has deliberated an emerging CAD system for the detection of glaucoma, hypertensive retinopathy and diabetic retinopathy. This system uses retinal fundus images for the detection of these diseases. [14] Many automated systems for retinal image analysis in order to correctly classify the patients with Diabetic Retinopathy are proposed. [30] SIVA is a semi-automated system developed by National University of Singapore for analyzing the vascular system of eye. [8] There are some Software packages available, which allow processing of data gathered from these systems: ADRES 3.0 is used for the grading of diabetic retinopathy developed by Perumalsamy et al. It has been commercialized and deployed in

diabetic centers and general physician clinics in India for use. [31] The clinical trials for the diagnosis of several ocular diseases is being run by Singapore Eye Research Institute. It is also running clinical trials for pathological myopia (PM), diabetic retinopathy and age related macular degeneration (AMD), using a uniform set of ophthalmic image reading and analysis protocols. [42] There are two recent works on ocular disease diagnosis based on clinical data. Liu et al. [23] developed an architecture of automatic glaucoma screening and diagnosis. The architecture is known as (AGLAIA-MII) automatic glaucoma diagnosis through medical imaging informatics. It provides glaucoma diagnosis by combining patient's personal data, Digital Fundus Photographs' imaging information and genome information. Features were extracted automatically from each data source. Subsequently, these features were passed to a multiple kernel learning (MKL) framework. This MKL generate a final diagnosis as an outcome. In another work, Zhang et al. [46] proposed a framework of computer-aided diagnosis for Pathological Myopia (PM). It is based on Biomedical and Image Informatics. Data from these heterogeneous data sources contains fundus images, demographic/clinical and genetic data. The framework proposed by Zhang et al. combined these data to enrich the understanding of Pathological Myopia, it provides a complete information of the risks factors involved and improves the diagnostic outcomes. A data-driven approach was proposed to exploit the growth of heterogeneous data sources to improve assessment outcomes.

One of the pioneer research works on Clinical Decision Support Systems (CDSS), was developed in late 1970s to assist in the diagnosis of glaucoma. The system is known as CASNET (causal-associational network). [44] In CASNET, clinical data is used. This data covers symptoms reported by the patient, such as, 'ocular pain', 'decreased visual acuity'. It also covers various eye examination results, such as, visual acuity, IOP, anterior chamber depth, angle closure, pupil abnormality and corneal edema. [20] A descriptive model of the disease process is used in CASNET logical interpretations of clinical findings for glaucoma diagnosis. The model had a semantic net with weighted links representing pathophysiological mechanisms. It represented early medical expert systems. The framework of CASNET describes the knowledge of expert consultants and simulates various aspects of the cognitive process of clinicians. In 2002, Chan et al. reported the most initial implementation of Support Vector Machines (SVM) for glaucoma diagnosis. [6] The Standard Automated Perimetry (SAP), a common computerized visual field test produced the output of the Clinical data used in the research. The authors equated the performance of various machine learning algorithms with SAP output. Multilayer perceptron (MLP), SVM, Linear and Quadratic Discriminant

Analysis (LDA and QDA), Parzen window, mixture of Gaussian (MOG), and mixture of generalized Gaussian (MGG) were the machine learning algorithms that were included for the study. It was witnessed that machine-learning-type classifiers displayed enhanced performance over the best indices from SAP. Moreover the authors also deliberated upon the benefit of using feature selection to additionally improve the classification accuracy with a prospect to diminish testing time by considerably reducing the number of visual field location measurements. In 2011, Bizios et al. carried out a study examining the data fusion methods and techniques for simple combinations of parameters retrieved from SAP and measurements of the Retina Nerve Fibre Layer Thickness (RNFLT) obtained from Optical Coherence Tomography (OCT) for diagnosis of glaucoma using Artificial Neural Networks. [3] The results indicated that the diagnostic precision from a blend of fused SAP and OCT data was much greater than using either of the two separately. This was the first every testified study using fused data for glaucoma diagnosis. A new study reconnoitered the association between the central corneal thickness (CCT), Heidelberg Retina Tomography II (HRTII) structural measurements and IOP using a pioneering non-linear multivariable regression method, for the purpose of outlining the risk factors in future glaucoma advancements. [21] Barella et al. investigated the diagnostic proficiency of machine learning classifiers (MLCs) and random forest (RF) using RNFL and optic nerve data. [2] The end result was 0.877 of area under the ROC value using RF.

III. Problem Definition

The research is multidisciplinary in nature, involving computer science as well as medicine domain. Information was gathered on various fields of medicine where automated diagnosis was required such as, radiology, cardiology and ophthalmology. The Ophthalmic diseases lack fatality, but have tendency to progress overtime leaving permanent disability-morbidity, that have more impact on daily life of the patients. [13] In this context, the Indian population is more vulnerable to these diseases due to their genetic predisposition, changing lifestyle and timely diagnosis of the disease. As the diseases are chronic and non-treatable at later stage, they impose heavy economic and social burden to over developing economy in the form of loss of working hours and treatment cost.

The identified issues in research from literature study are:

1. The diagnosis in medicine is more complicated than in other areas because of medical terms, semantic relations and amount of data involved in process of diagnosis. It deals with significant amount of analysis though advanced investigating equipment,

producing minute examination data as well as analysis of such data in the form of numeric, bar charts, line charts etc. This requires specially designed intelligent system for complex data and analysis process.

2. In India, most of the healthcare delivery systems are based on manual record keeping or Electronic Health Record Systems (EHRs) which helps in maintenance of patient history. Presently accuracy of diagnosis depends on the human attributes such as, past experience and domain specific knowledge, using which, practitioners are concluding their diagnosis. Patients are required to consult more than one doctor for second opinion, which is costly in monetary terms as well as time consumption. An intelligent system can very well address such issues.

The research was carried out in the area of Artificial Intelligence-Machine Learning, more particularly with reference to the suitable Classification and Prediction Algorithms of Artificial Intelligence-Machine Learning. The research also encompasses the development of new algorithms/techniques and testing them in the domain of Ophthalmology for diagnosing various stages of Glaucoma- an eye disease.

IV. Objective and Scope of Work

The proposed system is intended to support clinicians at various stages in the eye care process, from preventive care through diagnosis, followed by proper treatment and medical advice. The system would be used to seek second opinion for the practitioner and would be able to facilitate remote diagnosis at lower costs, improved efficiency & speed, and reduced doctor's physical intervention at the patient's examination site.

The trade-off between prediction power and interpretability is one of the well-known issues in machine learning. The black box models such as Support Vector Machine (SVM) and deep learning algorithm show good prediction power. However, it is difficult to understand how the model gives the prediction result. Therefore, they are not entirely suitable for medical diagnosis because clinicians want to know both the prediction and the reason for the prediction. [43] Decision tree models [22] such as C5.0 [32] [33] show good interpretability and poor prediction power. Logistic Regression and Naïve Bayes are algorithms used for probabilistic classification [7].

Objectives of the Research:

1. To determine the patient wise classification of glaucoma conditions (types).
2. To study and analyze various techniques for detection of glaucoma types conditions (types) in patients.
3. To identify the most appropriate detection technique for different conditions (types) of glaucoma.
4. To explore and analyze new techniques / algorithms for diagnosing various conditions (types) of glaucoma in patients.
5. Devising appropriate techniques / algorithms for testing diagnosis of various conditions (types) of glaucoma and studying the efficacy of these techniques.

The goal of this research was to develop an Intelligent System that has strong prediction power and an equally good results' interpretability for diagnosis of various stages of glaucoma. To achieve the goal, an ensemble algorithm was developed for selecting good features from clinical eye examination data for classification and prediction. To develop the new algorithm, the existing algorithms C5.0, RF, SVM, and k-nearest neighbour (KNN) algorithms, Naïve Bayes, Multilayer Perceptron, J48 were tested.

V. Thesis Contribution

The research uses artificial intelligence (machine learning) techniques for diagnosis of Glaucoma. The main contributions of the thesis are:

1. A survey of state of the art of the artificial intelligence techniques used for eye disease diagnosis mainly Glaucoma diagnosis.
2. A literature review on classification techniques used for diagnosis of various conditions (types) of Glaucoma.
3. Study and analysis of different classification techniques for Glaucoma diagnosis.
4. Design and develop hybrid classification techniques to obtain high classification performance.

VI. Methodology of Research, Results / Comparisons

1. Methodology of Research

This research is multidisciplinary and diagnostic. It is multidisciplinary since it maps some domains of Computer Science and Ophthalmology which is a branch of medicine. It is also diagnostic as it follows case-based method using in depth approaches of various classification techniques of computer science to reach basic causal relations. The sample size is also small and require deep probing data gathering devices used in ophthalmology.

The sample size is 163. Out of these 163 samples 107 were used for training set and 56 were used for testing set.

i. Profile of Respondents

DEMOGRAPHIC PROFILE OF PATIENTS

AGE

Age Groups	No. of Patients	% Patients
25-44	21	12.88
45-64	92	56.44
65-79	43	26.38
Above 80	7	4.29

Table 1.0: Table showing Demographic Profile of Patients Age Groups

The data collected from the patients was categorized into 4 classes based on the Age structure suggested by the Census 2011 of India.

In the patient's data 12.88% patients were found to be in the ages between 25 years and 44 years. 56.44% patients were found to be in the ages between 45 years and 64 years. 26.38% patients were found to be in the ages between 65 years and 79 years whereas 4.29% patients were above the age of 80 years.

GENDER

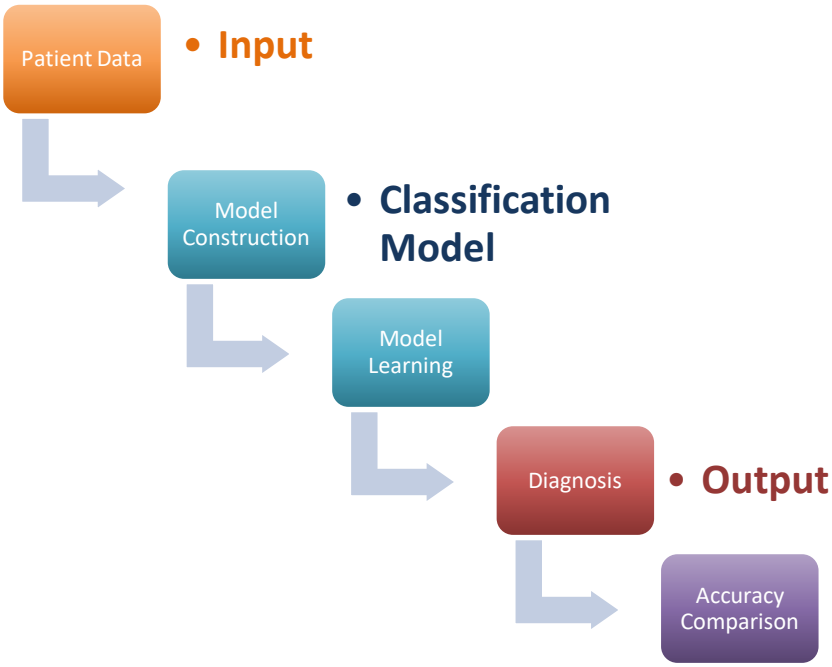
Gender	Nos.	%
Male	106	65.03
Female	57	34.97

Table 2.0: Table showing Demographic Profile of Patients Gender Groups

The data collected from patients was categorized into 2 classes based on the Age structure suggested by the Census 2011 of India.

From the collected data, 65.03% patients were Males and 34.97% were Females.

ii. Flow of Research



The Dataset used in this research was obtained from practitioner. The data was validated by the practitioner. It was normalized and standardized. The training set was used for construction of a classification model. The model was constructed using 10-fold cross validation. The model learning was carried out using training set. It was used for classification of the testing set. The model provided diagnosis of various conditions (types) of glaucoma disease. The accuracy obtained by the model was compared with other models found in the literature review.

iii. Configuration of Classifier

The Classifier for diagnosis of various conditions of Glaucoma, was using ensemble of more than one classifiers. The configuration of Multi-classifier was Parallel Configuration for combining classifiers. [48] The classifiers used for Multi-classifier were Neural Network classifier, Decision Tree classifier and Naïve Bayes classifier. These classifiers were further optimized to improve accuracy. The decision logic, which provides final classification from different classifiers was also optimized to nullify the bias of individual classifiers.

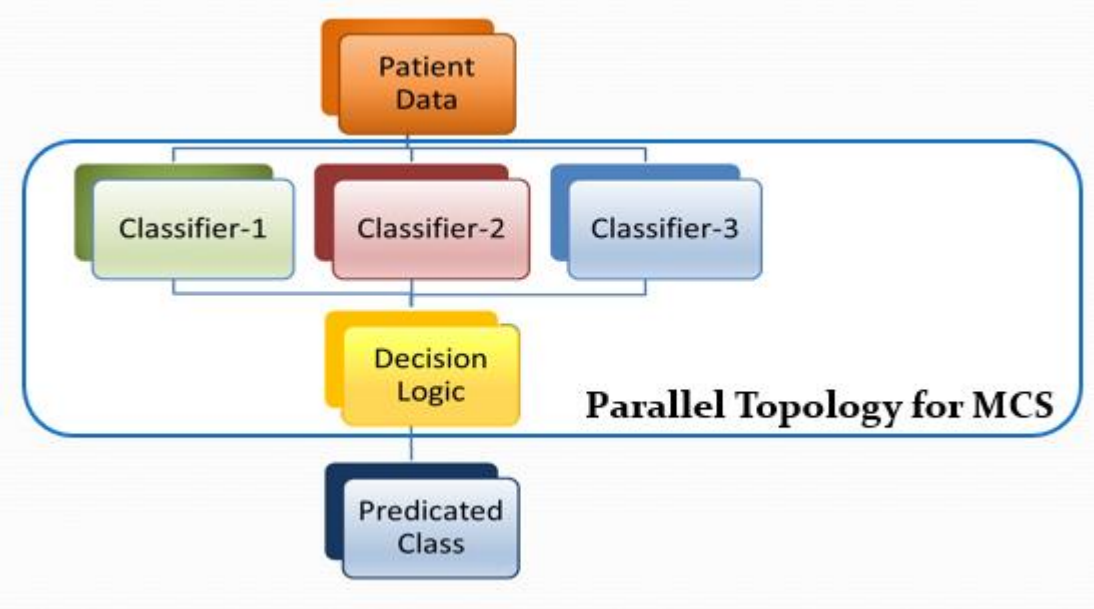


Fig. 1.0 Multi-classifier model

2. Results/Comparison

The ensemble classifier showed improved accuracy compared to individual classifier. The ensemble classifier accuracy was compared with other classifiers' accuracy found in literature review. The accuracy of Multi-classifier was 98.77%, which was higher than the accuracy given in Table 3.0.

Accuracy of different techniques for Glaucoma diagnosis				
Sr. No.	**Author**	**Parameters**	**Classifier**	**Measuring Parameter**
1	Nagaraj et al	Visual Disc	ANN	Sensitivity-95% Specificity-94% Accuracy-94%
2	Bizioz et al	Optic Nerve Head	ANN	Sensitivity-93% Specificity-94%
3	Nayak et al	Optic Disc, Blood Vessel	ANN	Sensitivity-100% Specificity-80%
4	Hung et al	RNFL Thickness	ANN	Area ROC-0.97
5	Chauhan et al	CDR, Perimetry, OCT	SVM	Sensitivity-84.1% Specificity-96.3% Accuracy-92.6%

Table 3.0 Accuracy of different techniques for Glaucoma diagnosis

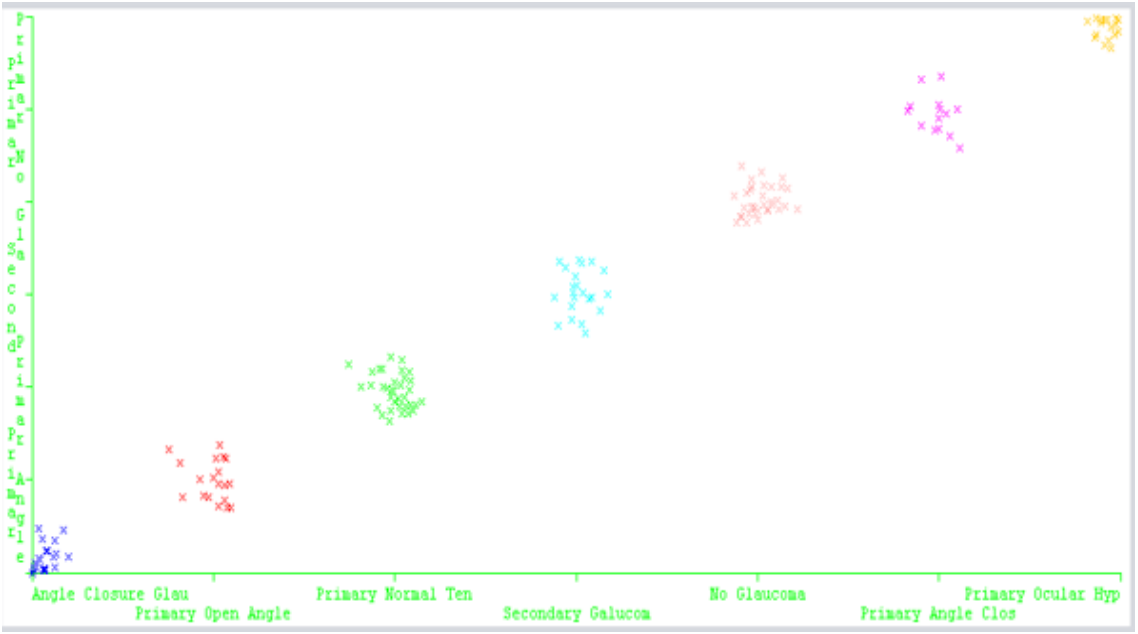


Fig. 2.0 Plot for Glaucoma Classification

VII. Achievement with respect to Objectives

1. The patients with age group 45-64 formed the major part of the data which was 56.44%. 26.38% patients were found to be in the age group 65-79 years. From the total data, 63.05% patients were male and 34.97% patients were female, representing the eye aliment.
2. Various classification techniques, such as, C5.0, RF, SVM, and k-nearest neighbour (KNN) algorithms, Naïve Bayes, Multilayer Perceptron, J48 were studied detection of glaucoma conditions (types) in patients.
3. The Ensemble Classifier technique gives improved classification accuracy compared to individual classifiers, such as, C5.0, RF, SVM, and k-nearest neighbour (KNN) algorithms, Naïve Bayes, Multilayer Perceptron, J48.

VIII. Conclusion

The data obtained from practitioner shows that patients with age group 45-64 formed the major part of the data, which was 56.44%. From the total data, 63.05% patients were male, representing the eye aliment. The ensemble classifier shows accuracy 98.77%, which is higher than accuracy of other techniques found in literature review.

IX. Papers published and a list of all publications arising from the Thesis

Sr. No.	Title of Paper	Publication / Presentation	Date	Publication/Presentation Details
1	Intelligent System using Neural Network Classifier for Glaucoma Diagnosis	Publication	Mar '18	UGC Approved, International Journal For Research in Applied Science and Engineering Technology, Volume 6 Issue III, ISSN : 2321-9653, March '18
2	OphthoIntelli-Doc:The Future of Ophthalmic Diagnosis	Poster Presentation	Oct '15	National Conference "Innovating for Development and Sustainability", Navrachana University, 30-31 Oct, '15
3	OpthoABM-An Intelligent Agent Based Model for Diagnosis of Ophthalmic Diseases	Publication	Dec '14	International Journal of Engineering & Computer Science(IJECS) ISSN : 2319-7242 Volume 3 Issue 12, Dec '14

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