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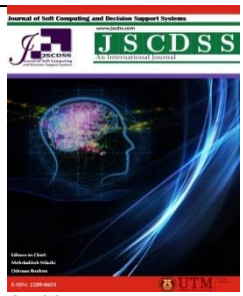

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Disease Diagnosis Using Machine Learning Techniques: A Review and Classification

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Abstract

In this research, we reviewed and classified academic conference and journal papers; which used data mining techniques in disease classification and diagnosis based on public medical datasets published between 2007 and 2019. The results of this review demonstrated that the application of data mining techniques in disease classification has experienced a dramatic rise in recent years. The finding of this paper also revealed that there was minimal focus on developing methods using incremental version of data mining techniques. We hope that this research will provide useful information about various data mining techniques, their application in disease diagnosis, and help researchers in developing medical decision support systems with insights into the state-of-the-art of development methods.

Keywords: Data Mining, Public Medical Datasets, Diseases Diagnosis, Literature Survey, UCI, PRISMA

1. Introduction

Data mining has been applied effectively in developing decision support systems to discover patterns in big datasets (Han et al., 2011). The potential of the data mining as an efficient disease classification tool was identified by World Health Organization (WHO) (Nilashi et al., 2016b). The use of data mining techniques in knowledge discovery for disease classification has been recognized as one of the interesting and important topics addressed by researchers (Ahmadi et al., 2018; Cauchi et al., 2015; Gopalakrishnan et al., 2010; Nilashi et al., 2016a).

There are many of supervised machine learning techniques for prediction and classification tasks (Kotsiantis et al., 2007; Nilashi et al., 2014a; Nilashi et al., 2014b; Nilashi et al., 2015a; Nilashi et al., 2015b). Using these techniques, several studies have developed methods for disease diagnosis and have been evaluated using real-world datasets (Çalişir and Doğantekin, 2011; Nilashi et al., 2019a; Nilashi et al., 2017a; Nilashi et al., 2017c; Polat, 2012). Hence, the classification of these studies based on applied machine learning techniques for investigating different types of disease diagnosis and reporting their outputs are important tasks; which this research aims to perform. Additionally, further researches should be

conducted to demonstrate the usefulness of machine learning techniques for disease classification, compared to other domains and based on their usage, the application of these techniques is less matured and has been rarely investigated. Therefore, the existing studies on disease classification which applied machine learning techniques need to be studied to show their contributions in disease diagnosis research. Accordingly, in this research we reviewed and classified the academic conference and journal papers which used data mining techniques in disease classification and diagnosis based on the public medical datasets of Repository of the University of California, Irvine (UCI) (Asuncion and Newman, 2007), which have been published between 2007 and 2019. We hope that this research will provide useful information about the adopted data mining techniques, their application in disease diagnosis and help researchers in developing medical decision support systems with insight into the state-of-the-art of development methods.

The rest of the paper is organised as follows. In Section 2, we present the research methodology that has been used in this study. In Section 3, we provide the results of the review of the selected research papers of disease diagnosis. Finally, the conclusion and future work is presented in Section 4.

2. Research Methodology

In this work, we have reviewed the selected research papers based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Budrionis and Bellika, 2016; Schraagen and Verhoeven, 2013; Zare et al., 2016). The aim of PRISMA is to help researchers in reporting meta-analyses results and conducting systematic reviews. Although PRISMA can't provide high quality assessment of a systematic review studies, this technique has proven to be a useful tool for critical assessment of published systematic reviews. On the other hand, PRISMA has well-defined steps which can help researchers in identifying, interpreting and evaluating the research papers' data effectively. In this review, we followed three main steps of PRISMA (searching the literature, selecting the eligible papers, and extracting and summarizing the papers' data) and accordingly classified the reviewed papers. In our review, in order to conduct PRISMA methodology, three main steps of PRISMA need to be accomplished which are literature search, study selection and data extraction and summarization.

2.1 Literature search

In the first step of PRISMA, we selected the major databases to conduct our review and provide a comprehensive review of the application of data mining techniques in disease classification. We selected the following databases: Scopus and Google Scholar. These databases are selected according to their popularity in health and computer science researches. The papers that have been published in conferences and academic journals on these databases are considered in this research and the literature search is performed based on the following terms: "Diseases Classification and Prediction" combined with each keyword of "Machine Learning", "Data Mining" and "Repository of the University of California, Irvine (UCI)". We considered their combinations for "Diabetes", "Heart", "Parkinson" and "Breast Cancer". As we found from the literature that the application of data mining techniques in disease diagnosis is relatively new, accordingly papers were collected from 2007 to 2019.

2.2. Study selection and eligible papers

In the second step of PRSIMA, full texts of the selected research papers, which have been identified and included from the first stage of PRISMA, have been reviewed carefully by the authors. This step helped us to select the research papers which were suitable and eligible for the inclusion in our review. To do so, papers which had applied data mining technique in disease diagnosis and performed the experiments based on the UCI datasets for the four diseases were chosen. In addition, unpublished papers, papers that provided the abstracts only, non-English papers, and book chapters were excluded. Furthermore, we also excluded the papers that failed to explicitly provide the used data mining technique. Note that the majority of papers which have been excluded in this phase were those papers that did not use public medical datasets in UCI in their experiments.

2.3. Data extraction and summarizing

In the final step, based on PRISMA guideline, the extracted research papers in the previous phase were summarized and the results were presented. In this step of PRISMA, summarizing and categorizing papers enabled the authors to obtain several critical and impressive hints about the use of data mining techniques in disease classification. Based on the results of this stage, we could accordingly find the limitations of previous studies and provide some directions and guidelines for future studies.

3. Results

We first reviewed the research papers which used data mining techniques for disease classification. The reviewed papers are listed in Table 1 (see Appendix A). We focused on four types of diseases which are Heart, Diabetes, Breast Cancer and Parkinson. In addition, all papers which have been listed in this section have used UCI public datasets in their experiments. Next, we classified the papers based on different perspectives. In this review, the academic papers were classified based on different main categories which utilized data mining techniques, year of publication in which they have been published, and types of diseases.

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3.1 Classification of Papers

The distribution of data mining techniques that were applied in disease classification is presented by publication year between 2007 and 2019 (see Fig. 1 in Appendix B). In terms of Parkinson, Breast Cancer, Heart and Diabetes diseases, the following methods were used from 2007 to 2019: SVM (36.2%), KNN (20.3%), NN (33.33%), ANFIS (4.3%), Fuzzy Logic (21.7%), K-Means (2.9%), GP (7.2%), EM (10.1%), PCA (10.1%), Random Forest (2.9%), LDA (7.2%), DT (7.2%), Association Rules (7.2%), PSO (5.8%), NB (11.6%), Regression (5.8%) and Deep Learning (10.1%). Specifically, the total number of methods that were utilized for Parkinson, Breast Cancer, Heart and Diabetes diseases are 54 in the time period of 2010 to 2018, 24 from 2007 to 2017, 44 from 2008 to 2018, and 21 from 2008 to 2019, respectively.

Among all of these techniques, the most widely used approaches were SVM, NN and Fuzzy Logic. For example, let pick SVM has the highest percentage as it was applied for Parkinson disease with 11.6%, Breast Cancer disease with 6%, Heart disease with 11.6% and Diabetes disease with 7.2%.

The frequency of data mining applications in disease classification studies has been relatively low between 2007-2011 and relatively high between 2011-2019. In 2018, 14 research papers in different areas of disease classification were published. The application of data mining in disease classification have experienced a dramatic rise, reaching to the peak of 14 papers in 2018 and 13 papers in 2016. Parkinson, Breast Cancer, Diabetes and Heart disease studies have adopted data mining methods with 31, 18, 10 and 19 research papers from 2007 to 2019, respectively. The distribution of academic papers of Diabetes disease was quite low from 2007 to 2019; however, Diabetes disease was widely investigated between 2009 to 2019 and reached the peak (up to 7 research papers) in 2016, after that, Diabetes studies decreased gradually to 5 research papers in 2019. Additionally, both Heart and Breast Cancer diseases had similar trends in 2007, 2014, 2015, 2017, 2018 and 2019 (see Fig. 2 in appendix B). In average, from this chart we can see that, in recent years researchers were more motivated to employ data mining techniques for disease classification. This may be referred to the emerging new data mining techniques and their algorithmic improvements over the last years as they have been adopted for classification tasks in different domains.

Distribution of papers based on the application of data mining techniques is presented in Table 1 in Appendix A. From Table 1, it is clear that SVM, NN and fuzzy logic methods are the most popular data mining techniques for disease classification comparing to other techniques (Adeli and Neshat, 2010; Agrawal and Jayaswal, 2020; Ahmadi and Akbarizadeh, 2018; Ahmadi et al., 2019).

Distribution of research papers conducted for investigating different diseases is shown Table 1 in Appendix A. In general, heart and Parkinson diseases gained researchers' attention as more researchers have focused on these diseases in their studies. These diseases were followed by breast cancer and diabetes diseases. It should be noted that based on the chart, the highest rank of published papers has been in 2016 for Parkinson disease. In Table 1 (see Appendix A), we summarize the employed data mining techniques for exploring different diseases along with the publication year of papers.

4. Discussion

The results of reviewing previous studies presented in this work have several important implications:

- In this review, we found that data mining techniques have contributed significantly in developing methods for disease classification. These methods have been evaluated to classify diseases based on a number of real-world datasets, however, most of the methods developed by supervised methods do not support the incremental learning and only about 1% of methods can support incremental version of data mining techniques.
- Developing efficient frameworks for big data analytic in the healthcare is one of the most important tasks; which should be taken into consideration. Developing a well-designed method for disease diagnosis from big data in healthcare is important. Disease diagnosis system developers need to consider the data sharing mechanism, privacy of data, the security of data, and the growth of data size. Moreover, in data mining it is important to develop methods for disease diagnosis to be modified for big data environment easily.

5. Conclusion and Future Work

This review investigated the applications of data mining techniques for disease classification. We have reviewed previous research papers which used data mining techniques in disease classification which have been published between 2007 and 2019 in the Scopus and Google Scholar databases. These databases were selected according to their popularity in health and computer science research. We focused on the studies that applied data mining techniques to investigate four types of diseases which are Heart, Parkinson, Breast Cancer and Diabetes. All studies reviewed in this work used UCI public datasets for their experiments. We observed that the usage of data mining techniques in disease classification has experienced a substantial growth over the last years. The results from this review showed that a majority of the selected papers has combined data mining techniques in developing methods for investigating a specific disease classification. SVM, NN and Fuzzy Logic techniques were found as the most frequently applied data mining techniques in classification methods (Ahmadi, 2019; Ahmadi and Akbarizadeh, 2017; Wang and Tian, 2019). In addition, most of the studies have investigated Parkinson disease prediction (Parnetti et al., 2019).

The results also demonstrated that a significant number of studies have focused on accuracy improvements of

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disease classification, while other issues such as computation time (time complexity or scalability) of methods have been rarely investigated. More specifically, most papers developed data mining techniques were not suitable for incremental learning. In this review, we only surveyed research papers published focusing on four types of diseases. This research can be extended to consider other diseases, which might provide different results. In addition, for this review we only considered the application of data mining techniques in the studies which have used UCI public datasets in their experiments for Parkinson, Heart, Diabetes and Breast Cancer. Therefore, additional databases also need be considered to comprehensively cover the usage of data mining techniques for other types of diseases. Accordingly, we will continue our review in the future to classify research papers on an ongoing basis and based on the limitations of this review. The review in this study provides recommendations for researchers in their future studies. Based on the result of our review, we recommend the researchers to use not only UCI datasets, but also use large datasets in their experiments from other machine learning repository to ensure the effectiveness of the developed method. Focusing on large datasets not only allow them to test the accuracy of the adopted classification, but also can motivate them to develop methods for incremental learning for time complexity issue. We hope that this research will provide useful information about the data mining techniques, their application in diseases diagnosis and help researchers in developing medical decision support systems with insight into the state-of-the-art of development methods.

Appendix A

Table 1
Distribution of academic papers by publication year, disease and data mining techniques

Disease	Author	Methods																
		SVM	KNN	NN	ANFIS	Fuzzy Logic	K-Means	GP	EM	PCA	Random Forest	LDA	DT	Association Rule	PSO	NB	Regression	Deep Learning
Diabetes	(Polat et al., 2008)	*																
	(Aslam et al., 2013)	*	*					*										
	Kahramanli and Allahverdi (2008)			*		*												
	(Erkaymaz and Ozer, 2016)			*														
	(Ganji and Abadeh, 2011)					*												
	(Dogantekin et al., 2010)				*							*						
	(Temurtas et al., 2009)			*														
	(Çalişir and Doğantekin, 2011)	*										*						
	(Nilashi et al., 2018a)	*							*	*								
	(Hayashi and Yukita, 2016)												*					
	(Nilashi et al., 2017c)			*					*									
	(Maniruzzaman et al., 2017)															*		
	(Nilashi et al., 2018a)	*								*								
	(Kannadasan et al., 2019)																	*

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Table 1
Distribution of academic papers by publication year, disease and data mining techniques (Cont.)

Disease	Author	Methods																
		SVM	KNN	NN	ANFIS	Fuzzy Logic	K-Means	GP	EM	PCA	Random Forest	LDA	DT	Association Rule	PSO	NB	Regression	Deep Learning
Breast Cancer	(Şahan et al., 2007)					*												
	(Polat and Güneş, 2007)	*																
	(Übeyli, 2007)	*																
	(Marcano-Cedeño et al., 2011)			*														
	(Zheng et al., 2014)	*																
	(Chen, 2014)													*				
	(Bhardwaj and Tiwari, 2015)			*														
	(Onan, 2015)		*			*												
	(Karabatak, 2015)															*		
	(Abdel-Zaher and Eldeib, 2016)			*											*			
	(Sheikhpour et al., 2016)														*			
	(Chaurasia et al., 2018)			*												*		
	(Khuriwal and Mishra, 2018)		*															
	(Sakri et al., 2018)														*			
	(Kadam et al., 2019)																	*
	(Sri et al., 2019)	*	*															
	(Islam et al., 2017)		*															
	(Nilashi et al., 2017b)					*			*			*						

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Table 1
Distribution of academic papers by publication year, disease and data mining techniques (Cont.)

Disease	Author	Methods																
		SVM	KNN	NN	ANFIS	Fuzzy Logic	K-Means	GP	EM	PCA	Random Forest	LDA	DT	Association Rule	PSO	NB	Regression	Deep Learning
Parkinson	(Guo et al., 2010)							*	*									
	(Das, 2010)			*														
	(Nilashi et al., 2017a)								*	*			*					
	(Bhattacharya and Bhatia, 2010)	*																
	(Nilashi et al., 2019b)				*				*									
	(Åström and Koker, 2011)					*												
	(Li et al., 2011)					*												
	(Ozcift, 2012)	*																
	(Polat, 2012)		*			*	*											
	(Eskidere et al., 2012)	*		*														
	(Chen et al., 2013)	*	*			*				*								
	(Babu and Suresh, 2013)			*														
	(Peterek et al., 2013)										*							
	(Hariharan et al., 2014)			*					*	*		*						
	(Froelich et al., 2015)												*					
	(Khan et al., 2016)			*				*										
	(Buza and Varga, 2016)			*														
	(Naranjo et al., 2016)															*		
	(Al-Fatlawi et al., 2016)			*														
	(Jain and Shetty, 2016)		*	*										*				
	(Behroozi and Sami, 2016)	*	*													*		
	(Grover et al., 2018)	*																*
	(Gunduz, 2019)																	*
	(Wan et al., 2018)		*									*					*	*
	(Nilashi et al., 2018b)	*																
	(Johri and Tripathi, 2019)																	*
	(Abdar and Zomorodi-Moghadam, 2018)															*		
	(Avci and Dogantekin, 2016)							*										
	(Nilashi et al., 2018a)	*			*				*	*								

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Table 1
Distribution of academic papers by publication year, disease and data mining techniques (Cont.)

Disease	Author	Methods																
		SVM	KNN	NN	ANFIS	Fuzzy Logic	K-Means	GP	EM	PCA	Random Forest	LDA	DT	Association Rule	PSO	NB	Regression	Deep Learning
Heart	(Bhatia et al., 2008)	*																
	(Kahramanli and Allahverdi, 2008)			*		*		*										
	(Das et al., 2009)			*														
	(Adeli and Neshat, 2010)					*												
	(Soni et al., 2011)													*				
	(Gudadhe et al., 2010)	*		*														
	(Ghumbre et al., 2011)	*		*														
	(Anooj, 2012)					*												
	(Rout, 2012)					*												
	(Nahar et al., 2013)													*				
	(Shilaskar and Ghatol, 2013)	*																
	(Shao et al., 2014)			*														
	(Long et al., 2015)					*												
	(Nguyen et al., 2015a)					*		*										
	(Nguyen et al., 2015b)					*												
	(Kausar et al., 2016)	*					*			*								
	(Amin et al., 2019)	*	*	*									*			*	*	
	(Bashir et al., 2019)	*									*		*			*	*	
	(Pawlovsky, 2018)		*															
	(Darmawahyuni et al., 2019)																	*
	(Paul et al., 2018)					*												
	(Takci, 2018)	*	*	*										*			*	
	(Khourdifi and Bahaj, 2018)		*												*			

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Appendix B

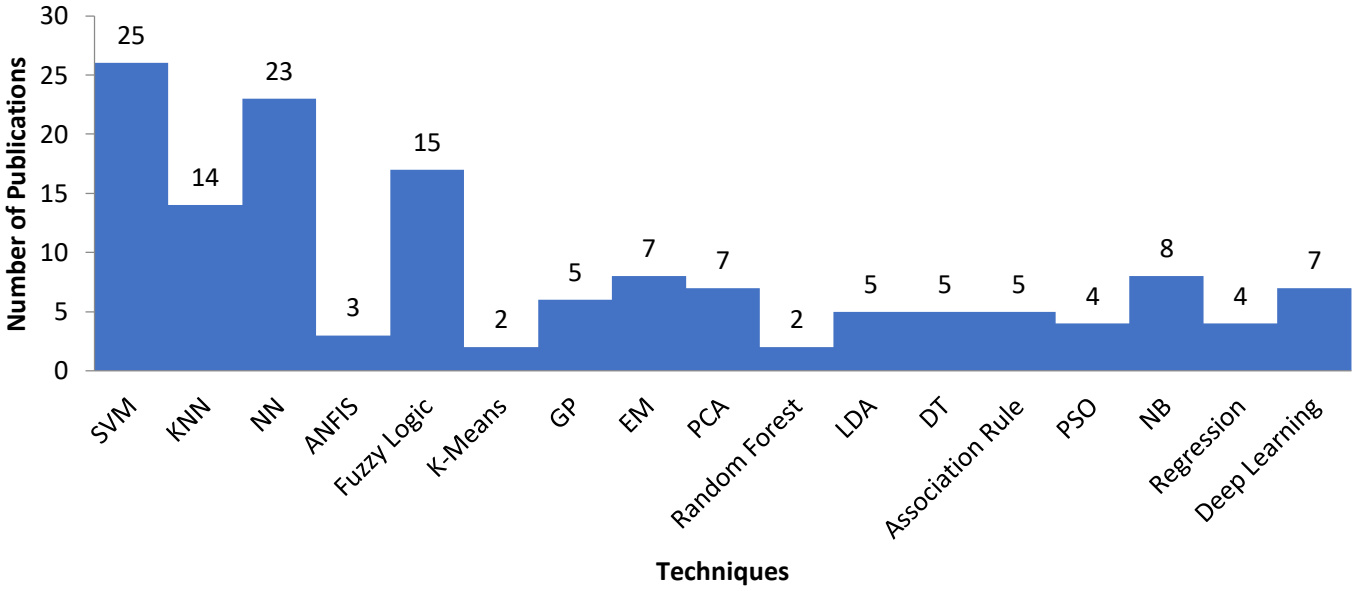

Fig. 1. Techniques and number of publications

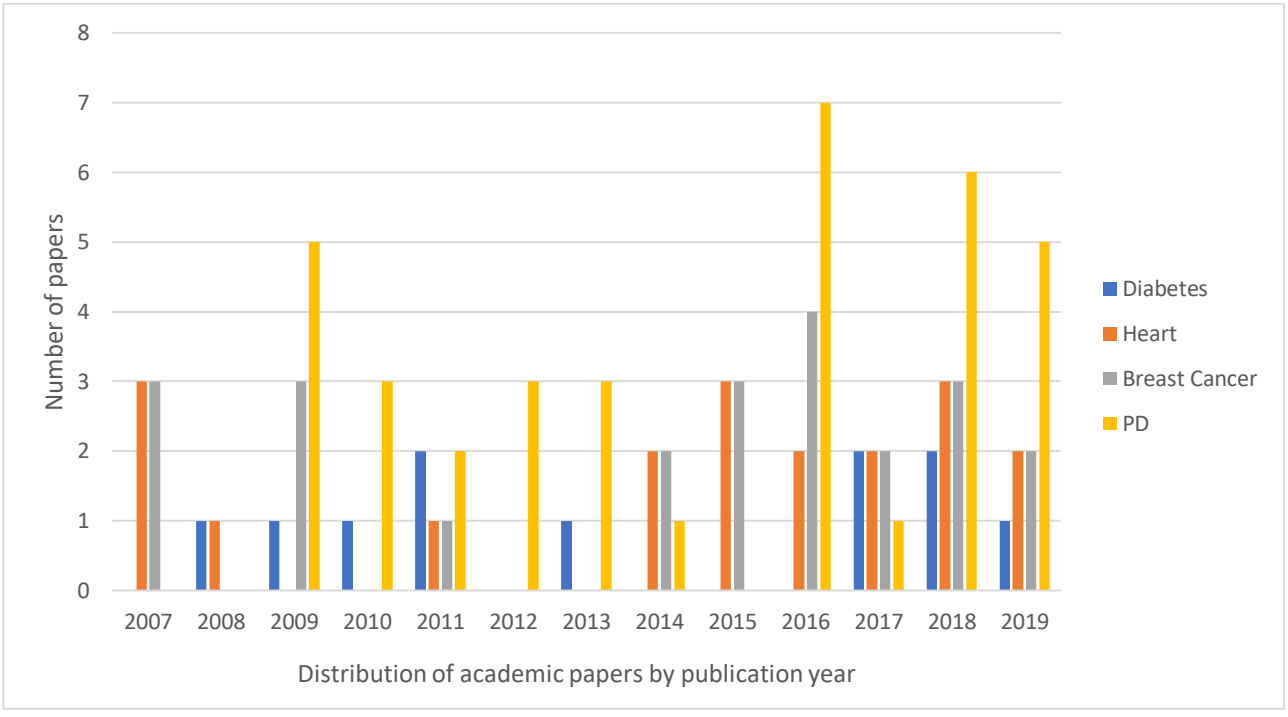

Fig. 2. Number of papers and distribution of academic papers by publication year

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