Swarm intelligence and data mining: a review of literature and applications in healthcare

Conference Paper · June 2019

DOI: 10.1145/3339311.3339323

3 authors:

Nandini Nayar
Chitkara University

Sachin Ahuja
Chandigarh University

Dr. Shaily Jain
Chitkara University

Swarm Intelligence and Data Mining: A review of literature and applications in healthcare

Nandini Nayar
Department of Computer Science and Engineering, Chitkara University Institute of Engineering and Technology,
Chitkara University, Himachal Pradesh, India
nandini.nayar@chitkarauniversity.edu.in

Sachin Ahuja
Chitkara University Institute of Engineering and Technology
Chitkara University, Punjab, India
sachin.ahuja@chitkara.edu.in

Shaily Jain
Department of Computer Science and Engineering, Chitkara University Institute of Engineering and Technology,
Chitkara University, Himachal Pradesh, India
shaily.jain@chitkarauniversity.edu.in

ABSTRACT

Healthcare industry is evolving at a rapid pace across the world. Substantial amount of heterogeneous data is generated by healthcare industry. It is crucial for healthcare industries to attain, accumulate and mine the data in an effective manner. Thus, data mining can provide enormous opportunities for diagnosis, prediction and essential treatment. Data mining plays imperative role in the medical domain that facilitates the systems to analyze the massive data, so that finest practices can be applied for further research and evaluating the patients' reports. This paper explores various applications that employ Swarm Intelligence with data mining in healthcare in terms of methods and results obtained. Swarm Intelligence algorithms have been used for prognosis of major diseases like cancer, heart diseases, tumors, and cardiology. The Swarm Intelligence approaches have been applied in the areas of disease diagnosis and treatment.

KEYWORDS

Swarm Intelligence, Data Mining, Medical, Healthcare

1 Introduction

Healthcare refers to the comprehensive process that can involve preclusion, diagnosis of various kinds of diseases or any other kind of injury in living beings.

ICAICR - 2019, June 15–16, 2019, Shimla, H.P, India © 2019 Association for Computing Machinery. ACM ISBN 978-1-4503-6652-6/19/06…$15.00 https://doi.org/10.1145/3339311.3339323

The healthcare applications that are prediction-based have tremendous commercial value that may include predicting health risk [1]. Data mining can also be used in healthcare for pertinent detection and preclusion of diseases and to identify the fraud insurance claims. In medical domain, data mining is beneficial to process enormous data associated with patients, diagnosis and their medicines [2].

1.1 Data mining in Health care industry

Data mining refers to the task of exploring useful and interesting patterns and associations in voluminous data. Data mining is valuable for healthcare organizations, insurance agencies and patients. Various data mining approaches have been used to classify chronic diseases and to identify high-risk patients. This will enable the healthcare industry to make a comparison of various symptoms, probable causes and necessary treatment strategy [3]. Various symptoms can be compared, their cause can be exposed, and consequently the most efficient strategy can be predicted for treatment. Thus, a benchmark can be established accordingly for treatment of specific kind of diseases.

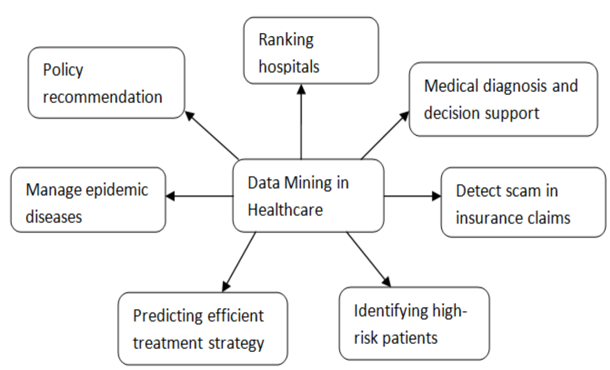

Figure 1: Data Mining benefits in Healthcare

[4] has summarized the valuable applications of data mining in medicine and public health as: Improvement of diagnosis, Prevention of patients' deaths, Non- invasive diagnosis and decision support. Other applications may include detection ,management of epidemic diseases, to discover side-effects of various kinds of drugs, detecting scams in insurance claims, Policy recommendation, to manage health records of specific individual and population health[5], Ranking of various hospitals, based on their capability to deal with high-risk patients.

1.2 Role of Swarm Intelligence (SI) in Data Mining

Healthcare datasets are complex and may comprise of a large number of features. Such datasets are referred as high-dimensional datasets. There are numerous ways to collect healthcare data that include pathology reports, surveys e.t.c that help to diagnose a disease. However, if the size of data increases, then it becomes difficult to analyze the data and perform predictions.

"Feature selection" refers to the initial phase of classification that helps to decrease the dimensions of problem, reduce noise, and enhance speed and eliminating non-relevant and redundant features [6].

To develop consistent data mining models, it is anticipated that features comprise of valuable information and dataset must have minimal features [7]. Thus, Swarm Intelligence (SI) can be used to select best subset of features. Moreover, accuracy of data mining methods largely depends on the features available in dataset and size of data set between testing and training sets [8]. Thus, it is a good practice to have least number of features and to identify which features are vital for the dataset that can affect the accuracy of result.

Swarm Intelligence algorithms are based on behavioral characteristics of insects or animals. Various Swarm Intelligence algorithms are ACO (Ant colony optimization), PSO (Particle Swarm optimization), firefly based algorithm, fruit-fly, glow-worm, Cuckoo search, Lion, Monkey, Bat, Wolf e.t.c. In the recent times, Swarm Intelligence (SI) algorithms have been employed in several application areas that involve engineering, bioinformatics, sciences and various industrial applications.

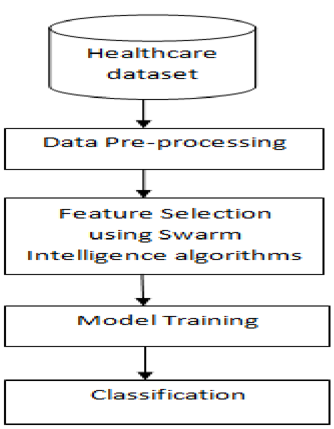

Fig.2 Process flow of Feature selection for classification

By applying feature selection methods on medical datasets, small subset of features can be extracted, that can be beneficial to reduce the effect of outliers and noisy data. Then classification can be applied for prediction and decision-making. Figure 2 demonstrates the process flow for selecting subset of features and using that feature subset for classification.

1.3 Challenges in healthcare systems

Tremendous data is available in healthcare systems. However, there is shortage of proficient analytical tools that can uncover hidden trends and relationships existing in data [9].Some more challenges in health care data mining include noisy data and problem related to sharing of medical data [10].

Data mining is a common approach for medical diagnosis. A major challenge in this field is that medical data may comprise of missing values which can decrease diagnostic accuracy [11]. Sharing of data among various healthcare organizations is also a challenge.

Medical data is quite complicated which makes it difficult to analyze. For making effective decisions, the accuracy and quality of data must be sustained.

Moreover, medical datasets may contain attributes that may be redundant and inappropriate, which may slow down the processing task and may affect the accuracy. Thus, there is a need for feature selection methods to augment the performance and accuracy of classification models [12]. For this purpose, Swarm Intelligence (SI) can prove to be a valuable approach.

2. Review of Swarm Intelligence approaches used in medical domain:

In recent years, many researchers have used the principles of feature selection in medical datasets that has significantly enhanced the accuracy of predicting various kinds of diseases.

In [13], SFLLF (Shuffled Frog Leaping with Levy Flight) algorithm has been proposed for feature selection, to identify informative genes. The results show that this method outperforms PSO, CS and SFL methods. This method yields accuracy of 100% with K-NN classifier for 8 datasets.

In [14], the applications of Particle Swarm Optimization and Parallel Particle Swarm Optimization (PPSO) in healthcare systems have been reviewed. In [15], a hybrid algorithm(PSOMLP) has presented excellent value of precision i.e. 0.930,recall of 0.920, F-measure of 0.925 and AUC of 0.958 for predicting the category of delivery, if risks are involved in pregnancy.

In [11], a method has been proposed for estimating missing data in breast cancer diagnosis that has produces superior results for accuracy, sensitivity and specificity.[16] Presents an idea of integrating SFCM and Artificial Bee Colony algorithm for medical image segmentation problem. Table 1 lists some of the Swarm Intelligence algorithms applied in medical datasets.

Table 1 Swarm Intelligence algorithms applied on medical datasets

Author	Dataset used	Technique	Accuracy
S. W. Fei [17], 2010	Arrhythmia cordis	PSO-SVM	95.65%
		BP-NN	83.700%
Wei et al. [18],2011	Graves' disease	BPSO-TLC with a P-value filter algorithm	72%
		C4.5	61.2%
		NB	58.4%
		SVM	66.4%
Neshat et al.[19],2012	Hepatitis	CBR-PSO	94.58%
		KNN	89.86%
		Naive Bayes	86.35%
		SVM	90.31%
Subanya et al.[20],2014	Heart disease	BABC– Naive Bayesian	86.4%
		Naive Bayes	83.1%
		SVM	81.5%
Dheeba et al.[21],2014	Breast cancer	Particle Swarm Optimized Wavelet Neural Network (PSOWNN)	93.67%
		SONN	89.87%
		DEOWNN	92.40%
Vijay et al. [22],2016	Brain Tumour	Enhanced Darwinian Particle Swarm Optimization (EDPSO)	95%
		PSO	92%
Yousefi et al. [23],2018	Leukemia	PSO/GA/FSVM	100%
	Colon cancer	PSO/GA/FSVM	96.67%
	Breast cancer	PSO/GA/FSVM	98%
Sawhney et al. [24],2018	Cervical Cancer	Binary Firefly(BFA)+Penalty+RF	97.36%
		RF	94.92%
Rashid et al. [25],2018	Diabetic Mellitus Diagnosis	ANN based ABC with Weight mutation	97.32%
		ANN	89.99%
		ANN based ABC	94.77

In [26], diabetes dataset is selected from UCI repository, where Ant Colony Optimization has provided best classification performance.

In [27]various Swarm Intelligence approaches have been applied for detection of diabetes disease risks in patients.

In [28], a remote health monitoring system based on swarm intelligence has been projected, that can detect crucial health-state of patient. In [29], a model has been developed for detection of erythemato-squamous disease that provides 98.91% accuracy.

This model is based on Particle Swarm Optimization, Support Vector machine and association rules. Swarm Intelligence algorithms have also been applied in the field of image segmentation, that can enable doctors to gain more meaningful information with more accuracy and in shorter time duration.

Various researchers have employed Swarm Intelligence approaches for medical image segmentation or thresholding [30],[31], [32], [33], [34].In [30], CCQPSO (Dynamic Context Cooperative Quantum-behaved particle swarm optimization) algorithm has been used for segmentation of medical images.

In [31], an approach has been proposed based on Linearly Adaptive PSO for diagnosis of caries-affected tooth with help of X-Ray images, that has accuracy of around 99%.

In [32], Modified Bacterial Foraging Algorithm(MBF) has been used for the task of image-segmentation(histogram-based).

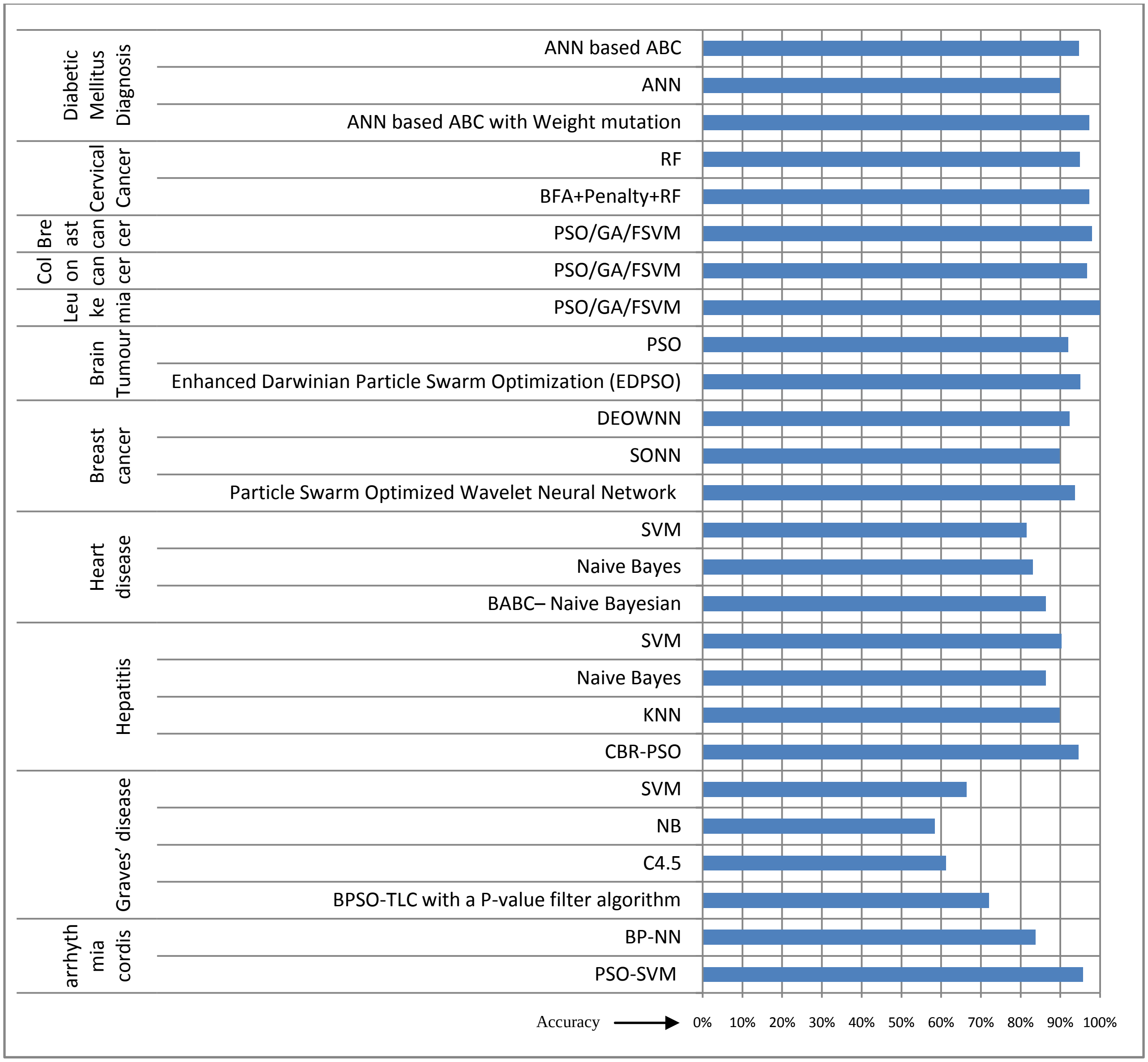

Fig. 3 Comparison of accuracy in various healthcare datasets

In [33], PSO is used to provide optimal threshold value in case of medical images. In [35], an image segmentation method PSO-SRG (Particle Swarm Optimization-Seeded Region Growing) that can be used in medical image segmentation as well.

[36] 3-dimensional medical image segmentation based on Ant Colony Optimization(ACO) has been presented that has been used for spleen-segmentation. In [37], PSO is used for planning of stereoactic body radiation. In [38], a computer-aided system has been developed for automatic diagnosis of lung tumors. Based on PSO with new inertia weight for NN. For solid nodules, this system has achieved an accuracy of 98%, for part-solid nodules, the accuracy is 99.5% and for non-solid nodules, the accuracy achieved is 97.2%.

In [39], a stochastic optimization technique that is based on Swarm Intelligence is used in lung SBRT (Stereoactic Body Radiation Therapy) for optimization of large scale non-convex problems. In [40], FSFCM (Firefly search with Fuzzy C Means) system has been proposed for automatic segmentation of lung nodules. In [41], a method has been proposed for lung tissue classification. In [42], Stochastic diffusion search has been applied for detection of metastasis in bone scans and to identify microcalcifications on mammographs. In [43], architecture has been proposed that integrates Swarm Intelligence with a Multi-Agent system for efficiency of healthcare systems. In [44], FOA-SVM (Fruitfly Optimization Algorithm with Support Vector Machine) is applied to medical decision making.

In [45], a coupled approach with jumping frogs and PSO has been found to be useful for estimating HIV-1 viral load. In [46], Swarm Intelligence techniques have been applied for estimating HIV-1 viral load with help of an interactive and efficient Graphical User Interface for estimating HIV-1 viral load from measurement of CD4 cell-count. In [47], feature selection is performed using Particle Swarm Optimization and Egyptian Vulture Optimization algorithms for diagnosis of Parkinson Disease. In [48], Tuberculosis bacteria is detected using microscopic imaging, based on firefly algorithm. In [49], Velocity Bounded Boolean Particle Swarm Optimization (VbBoPSO) and IVbBoPSO are used for diagnosing kidney and liver diseases. In [50], system has been proposed for diagnosis of cardiovascular diseases based on SVM, integrated with Binary Particle Swarm Optimization.

In [51], a machine learning technique has been proposed based on Grey-wolf optimization (GWO-ELM) for PQ (Paraquat) poisoning diagnosis. For this purpose, a real-life dataset of 103 patients was used for prediction of risk status.

3. Result

The following graph has been drawn based on data generated from the literature studied related to healthcare datasets.

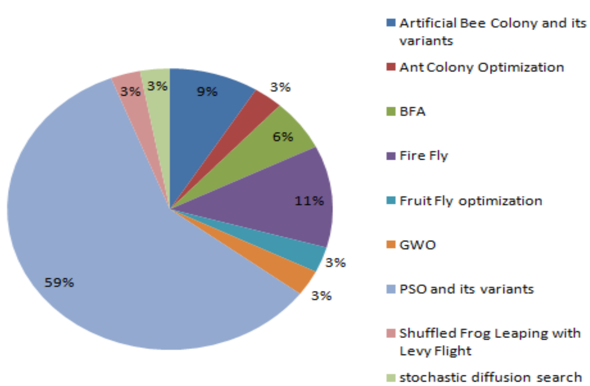

Fig. 4.Swarm Intelligence Algorithms used in Healthcare datasets

Figure 4 shows various Swarm Intelligence algorithms used in healthcare datasets, which undoubtedly demonstrates that PSO(Particle Swarm optimization) and the variants of PSO are the most popular algorithms used in medical applications.

4.Conclusion and Future Scope

In this paper, we have briefly reviewed numerous applications of Swarm Intelligence in healthcare. Swarm Intelligence algorithms can be successfully implemented in healthcare datasets and results prove that these algorithms yield accurate and valuable results. Since healthcare datasets possess large number of features which may be redundant or irrelevant too. With help of Swarm Intelligence algorithms, a valuable subset of features may be selected that enhances the performance of classifier, which can further lead to effectual decision making in medical datasets.

According to literature studied in this research paper, the most extensively used Swarm Intelligence approach in healthcare datasets is Particle Swarm Optimization and its variants. However, other Swarm Intelligence Algorithms like Antlion Optimizer (ALO), Elephant Search algorithm, Lion Optimization Algorithm(LOA), Cuckoo Search e.t.c are not much widely used for feature selection in healthcare datasets.

Moreover, many researchers have done extensive study on a certain kind of diseases like cancer, diabetes, heart disease, tumor that are available in online repositories like UCI, LIBSVM Data, e.t.c. This is the only limitation of this work. Swarm Intelligence algorithms must be extensively implemented for real time medical datasets that have thousands or millions of features. This would help to diagnose the diseases at very early stage and hence it can help in timely cure and prevention.

Future work can be done in this area by taking actual data from hospitals to find out more influential factors for early prediction of some diseases. Furthermore, data of other diseases can be incorporated , which are not touched upon by other researchers for timely prognosis using SI algorithms.

REFERENCES

[1] Zhang, Y., Qiu, M., Tsai, C. W., Hassan, M. M., & Alamri, A. (2015). Health-CPS: Healthcare cyber-physical system assisted by cloud and big data. IEEE Systems Journal, 11(1), 88-95.

[2] Husain, W., Yng, S. H., & Jothi, N. (2016, December). Prediction of generalized anxiety disorder using particle swarm optimization. In International Conference on Advances in Information and Communication Technology (pp. 480-489). Springer, Cham.

[3]https://the-modeling-agency.com/how-data-mining-is-helping-healthcare retrieved on 12 August, 2018

[4] Canlas, R. D. (2009). Data mining in healthcare: Current applications and issues. School of Information Systems & Management, Carnegie Mellon University, Australia.

[5] Raghupathi, W., & Raghupathi, V. (2014). Big data analytics in healthcare: promise and potential. Health information science and systems, 2(1), 3.

[6] Aghdam, M. H., Tanha, J., Naghsh-Nilchi, A. R., & Basiri, M. E. (2009). Combination of ant colony optimization and Bayesian classification for feature selection in a bioinformatics dataset. Journal of Computer Science & Systems Biology, 2(3), 186-199.

[7] Saurav Kaushik, "Introduction to feature selection methods with an example (or how to lead https://www.analyticsvidhya.com/blog/2016/12/introduction-to-feature-selection-methods-with-an-example-or-how-to-select-the-right-variables

[8] Jothi, N., & Husain, W. (2015). Data mining in healthcare–a review. Procedia Computer Science, 72, 306-313.

[9] Soni, J., Ansari, U., Sharma, D., & Soni, S. (2011). Predictive data mining for medical diagnosis: An overview of heart disease prediction. International Journal of Computer Applications, 17(8), 43-48.

[10] Ahmad, P., Qamar, S., & Rizvi, S. Q. A. (2015). Techniques of data mining in healthcare: a review. International Journal of Computer Applications, 120(15).

[11] Nekouie, A., & Moattar, M. H. (2018). Missing value imputation for breast cancer diagnosis data using tensor factorization improved by enhanced reduced adaptive particle swarm optimization. Journal of King Saud University-Computer and Information Sciences.

[12] Tomar, D., & Agarwal, S. (2013). A survey on Data Mining approaches for Healthcare. International Journal of Bio-Science and Bio-Technology, 5(5), 241-266.

[13] Gunavathi, C., & Premalatha, K. (2014). A comparative analysis of swarm intelligence techniques for feature selection in cancer classification. The Scientific World Journal, 2014.

[14] Elhoseny, M., Salama, A. S., Abdelaziz, A., & Riad, A. M. (2017). Intelligent systems based on loud computing for healthcare services: a survey. IJCIStudies, 6(2/3), 157-188.

[15] Moreira, M. W., Rodrigues, J. J., Kumar, N., Al-Muhtadi, J., & Korotaev, V. (2018). Nature-Inspired Algorithm for Training Multilayer Perceptron Networks in e-health Environments for High-Risk Pregnancy Care. Journal of medical systems, 42(3), 51.

[16] Singh, T. I., Laishram, R., & Roy, S. (2016). Combined spatial FCM clustering and swarm intelligence for medical image segmentation. Indian J. Sci. Technol, 9(45), 1-7.

[17] Fei, S. W. (2010). Diagnostic study on arrhythmia cordis based on particle swarm optimization-based support vector machine. Expert Systems with Applications, 37(10), 6748-6752.

[18] Wei, B., Peng, Q., Zhang, Q., & Li, C. (2011). Identification of a combination of SNPs associated with Graves' disease using swarm intelligence. Science China Life Sciences, 54(2), 139-145.

[19] Neshat, M., Sargolzaei, M., Nadjaran Toosi, A., & Masoumi, A. (2012). Hepatitis disease diagnosis using hybrid case based reasoning and particle swarm optimization. ISRN Artificial Intelligence, 2012.

[20] Subanya, B., & Rajalaxmi, R. R. (2014). Artificial bee colony based feature selection for effective cardiovascular disease diagnosis. International Journal of Scientific & Engineering Research, 5(5), 606-612.

[21] Dheeba, J., Singh, N. A., & Selvi, S. T. (2014). Computer-aided detection of breast cancer on mammograms: A swarm intelligence optimized wavelet neural network approach. Journal of biomedical informatics, 49, 45-52.

[22] Vijay, V., Kavitha, A. R., & Rebecca, S. R. (2016). Automated brain tumor segmentation and detection in MRI using enhanced Darwinian particle swarm optimization (EDPSO). Procedia Computer Science, 92, 475-480.

[23] Moteghaed, N. Y., Maghooli, K., & Garshasbi, M. (2018). Improving Classification of Cancer and Mining Biomarkers from Gene Expression Profiles Using Hybrid Optimization Algorithms and Fuzzy Support Vector Machine. Journal of medical signals and sensors, 8(1), 1.

[24] Sawhney, R., Mathur, P., & Shankar, R. (2018, May). A firefly algorithm based wrapper-penalty feature selection method for cancer diagnosis. In International Conference on Computational Science and Its Applications (pp. 438-449).

[25] Rashid, T., & Abdullah, S. (2018). A Hybrid of Artificial Bee Colony, Genetic Algorithm, and Neural Network for Diabetic Mellitus Diagnosing. ARO-The Scientific Journal of Koya University, 6(1), 55-64.

[26] Mishra, S., Mishra, B. K., Sahoo, S., & Panda, B. (2016). Impact of Swarm Intelligence Techniques in Diabetes Disease Risk Prediction. International Journal of Knowledge Discovery in Bioinformatics (IJKDB), 6(2), 29-43.

[27] Abed, S. E., Al-Roomi, S. A., & Al-Shayeji, M. (2016). Effective optic disc detection method based on swarm intelligence techniques and novel pre-processing steps. Applied Soft Computing, 49, 146-163.

[28] Arpaia, P., Manna, C., Montenero, G., & D'Addio, G. (2011). In-time prognosis based on swarm intelligence for home-care monitoring: A case study on pulmonary disease. IEEE Sensors Journal, 12(3), 692-698.

[29] Abdi, M. J., & Giveki, D. (2013). Automatic detection of erythemato-squamous diseases using PSO–SVM based on association rules. Engineering Applications of Artificial Intelligence, 26(1), 603-608.

[30] Li, Y., Jiao, L., Shang, R., & Stolkin, R. (2015). Dynamic-context cooperative quantum-behaved particle swarm optimization based on multilevel thresholding applied to medical image segmentation. Information Sciences, 294, 408-422.

[31] Sornam, M., & Prabhakaran, M. (2017). A new linear adaptive swarm intelligence approach using back propagation neural network for dental caries classification. In 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI) 2698-2703

[32] Sathya, P. D., & Kayalvizhi, R. (2011). Modified bacterial foraging algorithm based multilevel thresholding for image segmentation. Engineering Applications of Artificial Intelligence, 24(4), 595-615.

[33] Mishra, D., Bose, I., De, U. C., & Das, M. (2015). Medical image thresholding using particle swarm optimization. In Intelligent computing, communication and devices, Springer, New Delhi, 379-383.

[34] Mandal, D., Chatterjee, A., & Maitra, M. (2017). Particle swarm optimization based fast Chan-Vese algorithm for medical image segmentation. In Metaheuristics for medicine and biology (pp. 49-74). Springer, Berlin, Heidelberg.

[35] Mohsen, F., Hadhoud, M. M., Moustafa, K., & Ameen, K. (2012). A new image segmentation method based on particle swarm optimization. Int. Arab J. Inf. Technol., 9(5), 487-493.

[36] Galinska, M., & Badura, P. (2016, June). Swarm intelligence approach to 3D medical image segmentation. In Conference of Information Technologies in Biomedicine (pp. 15-24). Springer, Cham.

[37] Modiri, A., Gu, X., Hagan, A., & Sawant, A. (2015). Improved swarm intelligence solution in large scale radiation therapy inverse planning. In 2015 IEEE Great Lakes Biomedical Conference (GLBC) (pp. 1-4). IEEE.

[38] Nithila, E. E., & Kumar, S. S. (2017). Automatic detection of solitary pulmonary nodules using swarm intelligence optimized neural networks on CT images. Engineering science and technology, an international journal, 20(3), 1192-1202.

[39] Modiri, A., Gu, X., Hagan, A., Bland, R., Iyengar, P., Timmerman, R., & Sawant, A. (2016). Inverse 4D conformal planning for lung SBRT using particle swarm optimization. Physics in Medicine & Biology, 61(16), 6181.

[40] Parveen, S. S., & Kavitha, C. (2015, March). Segmentation of CT lung nodules using FCM with firefly search algorithm. In 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS) (pp. 1-6). IEEE.

[41] Tuba, E., Tuba, M., & Simian, D. (2017). Support vector machine optimized by firefly algorithm for emphysema classification in lung tissue CT images.

[42] Al-Rifaie, M. M., Aber, A., & Hemanth, D. J. (2015). Deploying swarm intelligence in medical imaging identifying metastasis, micro-calcifications and brain image segmentation. IET systems biology, 9(6), 234-244.

[43] Jemal, H., Kechaou, Z., & Ayed, M. B. (2014, August). Swarm intelligence and multi agent system in healthcare. In 2014 6th International Conference of Soft Computing and Pattern Recognition (SoCPaR) (pp. 423-427). IEEE.

[44] Shen, L., Chen, H., Yu, Z., Kang, W., Zhang, B., Li, H., Liu, D. (2016). Evolving support vector machines using fruit fly optimization for medical data classification. Knowledge-Based Systems, 96, 61-75.

[45] Kamalanand, K., & Mannar Jawahar, P. (2015). Comparison of swarm intelligence techniques for estimation of HIV-1 viral load. IETE Technical Review, 32(3), 188-195.

[46] Kamalanand, K., & Jawahar, P. M. (2014). A graphical user interface for resource limited estimation of HIV-1 viral load using swarm intelligence techniques. Journal of Bioinformatics and Intelligent Control, 3(2), 110-116.

[47] Dixit, A., Sharma, A., Singh, A., & Shukla, A. (2015). Diagnosis of Parkinson Disease Patients Using Egyptian Vulture Optimization Algorithm. In International Conference on Swarm, Evolutionary, and Memetic Computing(pp. 92-103). Springer, Cham.

[48] Ayas, S., Dogan, H., Gedikli, E., & Ekinci, M. (2015, May). Microscopic image segmentation based on firefly algorithm for detection of tuberculosis bacteria. In 2015 23nd Signal Processing and Communications Applications Conference (SIU) (pp. 851-854). IEEE.

[49] Gunasundari, S., Janakiraman, S., & Meenambal, S. (2016). Velocity bounded boolean particle swarm optimization for improved feature selection in liver and kidney disease diagnosis. Expert Systems with Applications, 56, 28-47.

[50] Sali, R., Shavandi, H., & Sadeghi, M. (2016). A clinical decision support system based on support vector machine and binary particle swarm optimisation for cardiovascular disease diagnosis. International Journal of Data Mining and Bioinformatics, 15(4), 312-327.

[51] Hu, L., Li, H., Cai, Z., Lin, F., Hong, G., Chen, H., & Lu, Z. (2017). A new machine-learning method to prognosticate paraquat poisoned patients by combining coagulation, liver, and kidney indices. PloS one, 12(10), e0186427.