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Deep Neural Network for Heart Disease Medical Prescription Expert System

Majzoob K. Omer[1], Osama E. Sheta[2], Mohamed S. Adrees[3], Deris Stiawan[4], Munawar A. Riyadi[5], Rahmat Budiarto[6]
[1]Faculty of Comp. Sc. & I.T., AL Neelain University, Khartoum, Sudan
[2,3,6]Faculty of Science, Zagazig University, Zagazig, Egypt
[2]College of Comp. Sc. & I.T., Albaha University, Albaha, Saudi Arabia
[4]Faculty of Computer Science, Sriwijaya University, Indralaya, Indonesia
[4,5]Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia

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ABSTRACT

One of the most common causes of death is Ischaemic heart disease (IHD). Clinical decisions are often made based on doctors' intuition and experience rather than on the knowledge-rich data hidden in the database, which leads to unwanted errors and excessive medical costs that affects the quality of service provided to patients. On the other hand, there is lack of cardiologist and IHD specialist in developing countries. Therefore, the development of an expert system that improves the diagnostic and therapeutic decision model of IHD creates a universal need. The expert system is developed based on the cardiologist expertises in diagnosing IHD symtomps and the given prescriptions. This work attempts to increase the accuracy and the effectiveness of the expert system to treat IHD patient by leveraging deep neural networks and adopting deep learning strategy for Retristic Boltzman Machine (RBM). The deep neural network in this work has 152 neurons in the input layer, 52 neurons in the output layer, and 4 hidden layer. Experimental results show that the proposed system achieves up to 0.00974 error level in the training sessions and average improvement of 0.7322% in term of accuracy compared to expert system with standard machine learning in the testing phase. Some results that have discrepancies are consulted to the cardiologist to confirm the results.

Corresponding Author:

Majzoob K. Omer
Faculty of Comp. Sc. & I.T.,
AL Neelain University, Khartoum, Sudan.
E-mail: majzoob10@gmail.com

1. INTRODUCTION

Ischaemic heart disease (IHD) is related to various cardiovascular circumstances or risk factors and consequently, treatment can be complex. Thus, "treatment deserves a comprehensive management approach, including pharmacotherapeutic and invasive or surgical therapies, professional lifestyle interventions based on behavioural models of change, with different strategies from more basic, family-based to more structured and complex modalities, depending on the cardiovascular risk assessment and on concomitant diseases" [1]. Risk factor management concentrating on monitoring related cardiovascular risk factors, covering psychosocial support, physical activity advice and appropriate prescription of an adherence to cardio-protective drugs are integral to serving patients recover as normal a life as possible and advance their quality of life.

IHD is one of the most common causes of death in the world. This is the reason why the development of a broadly accepted expert system for accurately performing diagnostic and therapeutic decision model of ischaemic heart disease constitutes a general need. In addition, insufficient IHD specialist in developing countries especially in rural area requires a support of an expert system to help non-specialist to accurately diagnose and treat IHD patients.

Physicians need a systemic approach to actual clinical problems. Such a strategy ensures the maximum diagnostic accuracy at minimum risk and expense to the patient. Most cardiologists pursue a line of questioning to establish whether the actual chest pain is typically cardiac, a typical or non-cardiac in origin. It is therefore important to determine the sequence of the steps in the diagnosis of IHD. Clinical decisions are often made based on doctors' intuition and experience rather than on the knowledge-rich data hidden in the database. This practice leads to unwanted biases, errors and excessive medical costs which affects the quality of service provided to patients.

Many works (such as [2-6]) have already been carried out on the development of expert systems for IHD diagnosis and treatement with the use of intelligent systems such as fuzzy logic, genetic algorithm and artificial neural network. The existing expert systems using conventional neural network face problem with accuracy. This work attempts to develop an intelligent engine to improve the accuracy of such expert system by leveraging the deep learning concept. The expert system is expected to help cardiologists as well as general physicians (in case the absence of the cardiologists in rural area) to accurately treat the IHD patients.

2. RESEARCH METHOD

This work uses the deep neural networks due to its advantace in processing inter-related string/text input data.

2.1. Dataset

305 Patient clinical data related to IHD are collected from a hospital in Jakarta, Indonesia. The data is collected as symtomps and medicine prescriptions. Each patient information has ten attributes:

- Previous Disease Record (P1)
- Present Disease Record (P2)
- Personal Habit Record (P3)
- Physical Examination Results (P4)
- Cardio Vascular System (CVS)
- Respiratory System (RS)
- Per Abdomen (PA)
- Central Nervous system (CNS)
- Electrocardiogram (ECG)
- Blood Investigation (BI)

The details of the patient data/information are shown in Table 1 to Table 10.

Table 1. Physical Examination Results (P4)

Code	Disease
1	Altered consciousness
2	Orientation
3	Dyspnlow pulse ea
4	Fever
5	Low pulse rate
6	Normal pulse rate
7	High pulse rate
8	Low systolic blood pressure
9	Normal blood pressure
10	High blood pressure
11	Low respiratory rate
12	Normal respiratory rate
13	High respiratory rate
14	Pallor
15	Jaundice
16	Oedema feet
17	Perspiration
18	Saturation less than 90%
19	No abnormality detected (NAD)
20	Restlessness
21	Cyanosis
22	Irregular pulse
23	General condition – not satisfactory
24	Facial puffiness
25	Cold extremeties

Table 2. Previous Disease Record (P1)

Code	Disease
1	Hypertension
2	Diabetes Mellitus
3	TB
4	Bronchial Asthma
5	Hyperthyroidism
6	Hypothyrodism
7	Old IHD
8	Nil
9	Interstitial Lung Disease (ILD)
10	Cerebrovascular Accident (CVA)
11	Rheumatoid arthritis
12	Haemorrhoids (Bledding piles)
13	Rheumaticd heart disease
14	Atrial Fibrilation
15	Chronic Obstructive Pulmonary Disease
16	Supra Ventricular Techycardia (SVT)
17	Febroid with Menorrhagia
18	Dilated Cardiomyopathy

Table 3. Present Disease Record (P2)

Code	Disease
1	Chest pain
2	Retrosternal pain
3	Palpitations
4	Breathlessness
5	Sweating
6	Persipiration
7	Giddiness
8	Nausea/ Vomitting
9	Epigastric pain
10	Left arm pain
11	Syncope
12	Unconsciousness
13	Uneasiness/restlessness
14	Back pain
15	Heaviness in chest
16	Difficulty in breathing
17	Cough
18	Swelling over feet
19	Convulsion
20	Headache
21	Heartburn
22	Jaw/throat pain
23	Decrease apetite
24	Epistaxis
25	Haemoptysis
26	Both shoulder pain
27	Bleeding per rectum (PR)
28	Haemetemesis
29	Loose motion

Table 4. Personal Habit Record (P3)

Code	Disease
1	Smoking
2	Tobacco
3	Alcohol
4	Nil

Table 5. Cardio Vascular System

Code	Symptoms
1	Hearth sounds
2	Normal heart rate
3	Tachycardia
4	Bradycardia
5	Regular heart rhythm
6	Irregular heart rhythm
7	Gallop sound
8	No abnormality detected (NAD)

Table 6. Respiratory System

Code	Findings
1	Breath sounds preserved
2	Breath sounds reduced
3	Basal crepts
4	Ronchi
5	No abnormality detected (NAD)

Table 7. Central Nervous System (CNS)

Code	Findings
1	Consciousness
2	Orientation
3	Focal deficit
4	Restlessness
5	No abnormality detected (NAD)

Table 8. Per Abdomen (PA)

Code	Findings
1	Liver (hepatomegaly)
2	Spleen (splenomegaly)
3	Free fluid present
4	Abdominal distension
5	Obesity
6	No abnormality detected (NAD)

Table 9. ECG

Code	Disease
1	ST elevation
2	Anterior wall
3	Anteroseptal
4	Inferior
5	Inferoposterior
6	Lateral
7	Septal
8	High lateral
9	T wafe inversion
10	ST depression
11	QS complex
12	LBBB
13	Inferior and lateral (4&6)
14	Atrial fibrillation
15	RBBB
16	VBP's
17	Sinus tachycardia
18	Sinus rhythm
19	Supraventricular tachycardia SVT
20	Left ventricular hypertrophy (LVH)
21	Ventricular tachycardia/ fibrillation

Table 10. Blood Investigation (BI)

Code	Disease
1	Cardiac enzymes (High)
2	Blood sugar test normal
3	Blood sugar test low
4	Blood sugar test high
5	Kidney function test deranged
6	Lipid profile normal
7	Lipid profile abnormal
8	Complete blood count normal
9	Leukocytosis
10	Anemia
11	Thrombocytopenia
12	Urine routine
13	Troponin T/I (positive)
14	No abnormality detected (NAD)
15	Chest X-ray (cardiomegaly)
16	2-D-Echo RWMA
17	2-D-Echo LV CLOT
18	2-D-Echo LVH
19	Hypokalemia
20	Hyponatremia
21	Thyroid profile (abnormal)
22	2D-Echo – poor LVEF
23	Hypercalemia
24	Chest X-ray (COPD)

The medicines as treatments for the IHD along with their codes (MIDs) are shown in Table 11. While Table 12 and Table 13 show the twenty of clinical data examples on symptoms examinations, and the medicines prescribed by the physician, respectively.

Table 11. The Medicines and Their Codes

MID	Medicine name	MID	Medicine name
1	Alprazolam	27	Fortwin Inj
2	Amlodepine	28	Diazepam Inj
3	Aspirin	29	Nitroglycerin Inj
4	Atenolol	30	Ciprofloxacin Inj
5	Atorvastatin	31	Cardarone
6	Clopidogrel	32	Dobutamine Inj
7	DIGOXIN	33	Levolin (Nebolize)
8	Diltiazem	34	Methyl prednisolone
9	Diphenylhydantoin Sodium	35	Oral Hypoglycaemics
10	Enalapril	36	Lactulose syrup
11	Furosemide	37	Eltoxin
12	Ethamsylate	38	Dextrose 25% Inj
13	Insulin Inj	39	Dopamine
14	Iso sorbide dinitrate	40	Warfarin sodium
15	Losartan	41	Iron Capsule
16	Metoprolol	42	Neomercazole
17	Nikorandil	43	Betahistine HCL
18	Ondansetron	44	Kesol Syrup / Inj
19	Paracetamol	45	Vit -B12
20	Perindopril	46	Ethamysylate
21	Ramipril	47	Fen ofibrate
22	Trimetazidine	48	Inj Calcium Gluconate
23	Streptokinase Inj	49	(Glucose + Insulin) Drip
24	Taxim Inj	50	K-bind powder
25	Enoxaparin Inj	51	Syp.Gellusil / Mucaine gel
26	Rabeprazole Inj	52	Sucralfate Syp

Table 12. Examples of Symptoms Examinations of 20 Patients

P1	P2	P3	P4	CVS	RS	PA	CNS	ECG	BI
1	15,16	4	6,9,12	8	4	6	4	10	2
1,2	4,5	4	1,2,7,13,14,16	3,5	3	5	4	12	4
8	13,7,5	4	1,6,12	8	4	5	4	9	14
2	1,2,8	2	7,8,13,14	8	4	5	4	2	7
2	1,2,13,5	4	7,10	8	4	5	4	1,3	14
8	1,4	1	6,10	8	4	5	4	3	2
1	15,3,4	4	6,10,12	8	4	5	4	9	14
1,7	1,17	4	6,9	6	4	5	4	9	9
7	18	4	3,7,9,16	3	3	1	4	11,3	14
9,2,3	4	4	7,9,13,18	3	3,5	5	4	11,3	9,10,4
8	1,5	4	6,10	8	4	5	4	3	9,1,2
8	1	1	19	8	4	5	4	1,9	14,2
1,2,6	1,5,8	4	6,10,12,14	8	4	5	4	1,2	1,4,9,10
1,7	4,3,5,6,15	4	3,7,10,13,17,18	3	3,5	5	4	4,11	15
7,10	19	2	6,9,14	8	4	5	3	11,4	14
1	1	4	6,9,12	8	4	5	4	10,9	14
1,2,7	3,5,6,7	4	6,9,12	8	4	5	4	9	3
7	1	4	6,9,12	8	4	5	4	11,4	14
4	2,5,6,13	4	6,10,12,17,20	8	4	5	5	1,4	4,9,16,17
7	1,5,6,13	4	20,17,6,10,13	8	4	5	5	1,3,11,4	2,9,10,16,17

Table 13. The Corresponding Medicine Prescriptions for the 20 Patients

MD 1	MD 2	MD 3	MD 4	MD 5	MD 6	MD 7	MD 8	MD 9	MD 10	MD 11	MD 12	MD 13	MD 14	MD 15	MD 16	MD 17
11	13	14	17	3	5	7	10	29	19	30						
14	6	5	1	25												
1	3	5	6	13	14	17	19	21	23	25	26	27	29	36		
1	3	5	6	14	17	19	21	23	25	26	27	29	36			
3	14	19	15													
25	6	3	29	5	17	1	21	16								
14	3	5	6	1	26											
29	1	3	5	25	17	16	27	24								
32	11	20	33	14												
14	11	34	3	5	33	35	24									
23	1	5	6	29	25	17	31	16	21	36						
25	1	3	5	29	17	16										
23	25	26	27	28	29	13	1	3	5	16	17	18	21	37	6	36
11	21	29	1	3	5	17	7	28	19	15						
9	30	33	3	19												
14	1	3	5	2												
38	3	14	5	1												
25	2	3	5	6	29	17	16									
2	3	5	6	13	14	17	19	21	23	25	26	27	28	29	36	
2	3	5	6	14	16	17	19	21	25	26	27	28	29	36		

2.2. Deep neural network

Deep Neural Learning or Deep Neural Network (DNN) is a subset of machine learning in Artificial Intelligence (AI) that has networks which are capable of learning unsupervised from data that is unstructured or unlabeled. The deep neural network consists of more than 1 layer in its hidden layer [7-10]. The DNN in this work, has 152 neurons in the input layer, 52 neurons in the output layer, and 4 layers in the hidden layer. Each attribute of patient is represented by binary numbers. The number of digit representing the attribute depends on the number of fields shown in Table 1 to Table 10. The number of digit of P1=18, P2=29, P3=4, P4=25, CVS=8, RS=5, PA=6, CNS=5, ECG=21, BI=24. Thus, the total is 152 as the number of neurons for the input. Digit 1 represents that the symptom exists, otherwise is 0. For example, the input for the fourth patient record in Table 12 is as follows. 0110111 010000000000000000 11001000000010000000000000000 0001.

0000001001000000000000000 00000001 00010 000010 00010

101000000000000000000 000000000000001000000000. The output is medicine prescriptions as shown in Table 11. So, there are 52 neurons in the output layer. As illustration, the fourth patient's medicines prescription in Table 13 is represented as:

1010110000000100101010101110100000010000000000000000. Figure 1 illustrates the architecture of the DNN.

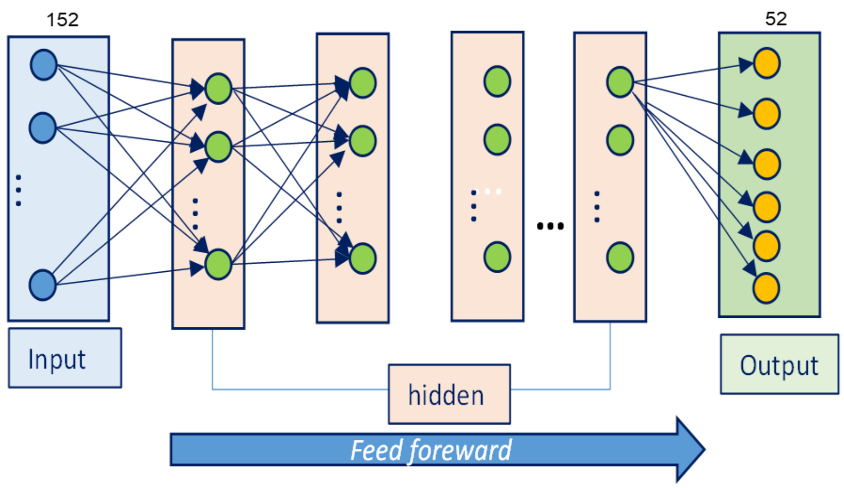

Figure 1. Architecture of the DNN

2.3. The Algorithm

This work adopts the deep learning method for Retristic Boltzman Machine (RBM) from the works in [6] and [7]. 250 patient's data are used for training and the other 55 data are for testing. The main aim of the RBM training algorithm is to maximize the product of probabilities assigned to some training set V (a matrix, each row of which is treated as a visible vector v):

$$\arg\max_{W} \prod_{v \in V} P(v) \tag{1}$$

The algorithm optimizes the weight matrix W [6]. The algorithm performs Gibbs sampling and is used inside a gradient descent procedure (similar to the way backpropagation is used inside such a procedure when training feedforward neural networks) to compute weight update. The basic, single-step contrastive divergence procedure for a single sample is summarized as follows:

a. Take a training sample *v*, compute the probabilities of the hidden units and sample a hidden activation vector *h* from the probability distribution.
b. Compute the outer product of *v* and *h* and call this the *positive gradient*.
c. From *h*, sample a reconstruction *v'* of the visible units, then resample the hidden activations *h'* from this. (Gibbs sampling step)
d. Compute the outer product of *v'* and *h'* and call this the *negative gradient*.
e. Let the update to the weight matrix ***W*** be the positive gradient minus the negative gradient, times some learning rate:

$$\Delta W = \in \left(vh^T - v'h'^T\right) \tag{2}$$

f. Update the biases *a* and *b* analogously:

Δa =∈ (v − v′)Δ{\displaystyle \Delta b=\epsilon (h-h')} (3)

$$\Delta a = \in (h - h') \tag{4}$$

2.4. Implementation

The algorithm is implemented using a high-end PC machine with the following specifications: Processor name: Intel Core i7-7700, Processor speed 3.8 GHz, RAM 16 GB, Storage 2.5 TB and Windows 10 O/S. Tensorflow utility/library is used on the Phyton platform.

3. RESULTS AND ANALYSIS

3.1. Training Results

Five (5) series of training were conducted with the same number of epochs. Figure 2 shows the training results. The average error is 0.009895. The training time was also recorded and in average the proposed system achieved a rational training time compared to the standard/conventional neural network. It was 15% slower.

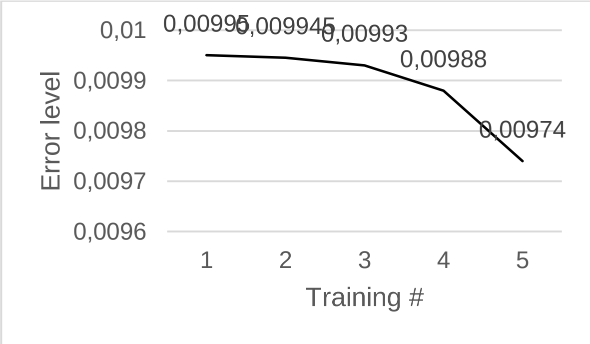

Figure 2. Training results

3.2. Testing Results

Fifty-five (55) data testing were used and some data that used during the testing. We compared the accuracy of the proposed expert system (using DNN) with standard/conventional Neural Network (NN). Five experiments are carried out and the results are shown in Figure 3. The average accuracy of the proposed expert system with DNN is: (99.60 +99.75+99.801+99.801+99.851)/5=99.7874%, whereas the average accuracy of the expert system with NN is: (99.16+99.002+99.1+ 99.002+99.012)=99.0552. Thus, the proposed expert system with DNN improves the accuracy with 0.7322%.

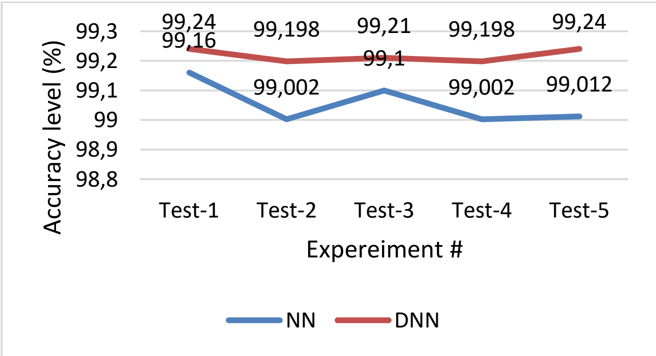

Figure 3. Accuracy of the proposed system

Table 14 shows the sample results of the testing that have discrepancies compared with the actual medicine prescriptions given by the physician. Analysis from the physician are given for some discrepancies of the results. For example, for patient number 4:

- Medicine no. 16 is suggested by the system as additional prescription. It is beneficial as it reduces the heart rate and thereby reduces workload and improves outcome.
- Medicine no. 19 is not given by the system. It is an antipyretic drug (to reduce fever) or an analgesic that if it is given, will not affect the cardiac outcome.
- Medicine No. 28 is injectable form of medicine no. 14 which the system has already prescribed.
- Medicine no. 36 is not given by the system. It is a laxative (Stool Softener) is given to patients who complain passing hard stools which cannot be judged by the system.

Table 14. Some Testing Results

Patient #	Ssytem's Prescription	Physician Prescription	Not prescribed	Additional prescription
1	1,3,5,6,14,25	3,5,7,10,11,13,14,17,19,29,30	7,10,11,13,14,17,19, 30	1,6
2	1,3,5,6,14,25	1,5,6,14,25	Nil	3
3	1,3,5,6,14,25	1,3,5,6,13,14,17,19,21, 3,25,26,27,29,36	13,17,19,21,23,25,26,27,29,36	Nil
4	1,3,5,6,14,16,17,21,23,25 ,26,27,28	1,3,5,6,14,17,19,21,23,25,26,27,29,36	19,29,36	16
5	1,3,5,6,14,25	3,14,15,19	15,19	1,5,6,25
6	1,3,5,6,14,25	3,5,11,14,24,33,34,35	11,24,33,34,35	1,6,25
7	1,3,5,6,14,25	1,3,5,6,14,26	26	25
8	1,3,5,6,14,25	1,3,5,16,17,24,25, 27,29	16,17,24,27,29	14
9	1,3,5,6,14,25	11,14,20,32,33	11,20,32,33	1,3,5,6,25
10	1,3,5,6,14,25	1,3,5,6,16,17,21,25,29	16,17,21,29	Nil

4. CONCLUSION

A deep neural network has been used to increase the accuracy of the expert system for IHD treatment. The proposed expert system that uses deep neural network has improved the accuracy by 0.7322% compared to the expert system that uses conventional neural network. in some cases, the system suggested new prescriptions for some patients, however, those prescriptions do not affect the cardiatic problems, according the advices from the physician. On the other hand, the medicines that were prescribed by the physician but were not prescribed by the system do not significantly affect the IHD. In other word, it increases efficiency in term of cost for IHD treatment.

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