DISK HERNIA DIAGNOSIS USING SIX BIOMECHANICAL FEATURES AND NEURAL NETWORK

A GRADUATION PROJECT REPORT SUBMITTED TO DEPARTMENT OF BIOMEDICAL ENGINEERING OF

NEAR EAST UNIVERSITY

By

Lael Rouhafzay

Mordecai M Maisaini

Nanbam C Shitery

In Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in

Biomedical Engineering Department

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Project Statement

All the information contained in this document has been prepared in the framework of academic rules and ethical rules. We declare that we prepare and deliver these rules and guidelines as required.

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ACKNOWLEDGEMENT

This project means we are approaching the last stages of our lives as undergraduate students and closing a chapter of a wonderful journey, it is the beginning of another long journey of real and practical life; this project will as the first attempt we make at serving humanity and pushing the efforts of science.

We are grateful for every person who participated and made effort to help us complete this project, we can't forget the role of the chairperson of biomedical engineering department Assoc. Prof. Dr. Terin Adali who was always ready to provide us assistance from the very first day we stepped our feet in this department. Then our supervisor Mr. Hasan Erdagli who had patience with us and spent time to help us finish this project, he made sure we were doing the right thing and always directed us on the right path.

Finally, we cannot forget to thank all family members and friends who stood beside us during this time.

ABSTRACT

Biomedical engineering as an interdisciplinary domain which is rapidly growing, must meet the needs of industrial, clinical, and scientific research communities. Artificial neural network (ANN) is one of the most successful technologies in the last two decades which has been widely used in a large variety of applications in various areas.

Applications in biomedical engineering area often involve analysis and classification of an experiment outcome. This can be obtained using traditional techniques such as linear discriminant function and the analysis of covariance. But in some cases, outcome of experiment is dependent on a number of variables, with the dependence usually an unknown nonlinear function. Neural networks can manage such problems. ANN bridges the much needed gap between technical knowledge and biology.

Investigation of ANN methods in biomedical engineering domain will advance medical care.

In the present work we have developed a neural network which assists to classify the patients into either normal or affected based on several factors.

The data based used in this network is some real data representing parameters related to disk hernia.

To evaluate the performance of the network the classification result by the neural network are compared with the real result also existing on the data base. The network could correctly classify 85.2% of all patients in data base.

Keywords: Neural Network; Diagnosis; Disk herniation

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CHAPTER 1

RESEARCH PURPOSE

1.1 Introduction

Disk hernia is a disease which affects the rubbery like part that cushions the spinal column.
The spinal disc consists of a hard exterior with a fluid like jelly encased in the interior, disc hernia (also known as ‘slipped disc’ in some cases) occurs when the hard exterior cracks or the disc shifts and the fluid within the disc leaks out.
Disc hernia mostly affects people within the age range of 30-50 years mostly affecting twice as much males than females.
There are two major forms of disc hernia; lumber disc hernia and cervical disc hernia: lumber disc hernia is more prevalent than cervical disc hernia.
It is still not certain if disc herniation can be treated using drugs, but most patients undergo treatment in order to correct this problem. As disc hernia is not a life threatening disease, some other patients can even go a life-time without correcting this issue.
Early detection of disc hernia is essential to improve the quality of life of patient as it puts an individual in a very uncomfortable situation as some patients with disc hernia cannot carry out even simple day to day activities. Most disc herniation are diagnosed by the physician mostly based on complains of the patient.
Our proposed system is to help in the diagnosis of disc hernia using some biological features or parameters gotten from an x-ray image of the spinal section of the patient. These parameters and the detection techniques will be discussed in more detail in a later section of this report.

CHAPTER 2

CLINICAL BACKGROUND

2.1 Anatomy and Physiology of the Spinal Column

The spinal column consists of a set of bones that forms the core of the back structure. It is made up of 33 bones which also houses the spinal cord which carries nerve impulses from and to the brain. The bones have hollows in them which the spinal cord passes through. They protect the spinal cord and aids in supporting the body's weight.

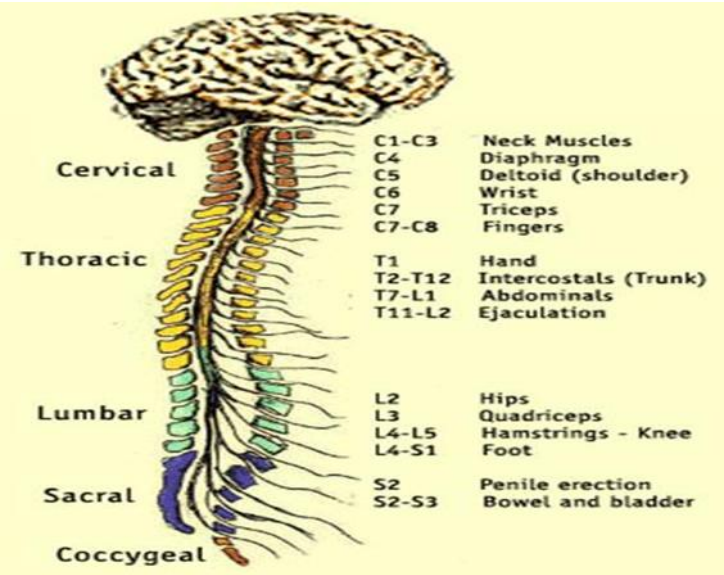


Figure 2.1 : Spinal column

2.2 Structure

The main parts of the spinal column consist of the bones, the spinal cord, the spinal discs, ligaments and tendons and the nerve roots, muscles surrounding the spine and the joints.

2.2.1 The Bones

Also known as the vertebrae, is made up of 33 bones. They have a hollow called the neural canal in which the spinal cord passes through. The vertebrae are separated into four regions which are cervical, thoracic, lumbar, sacrum and coccyx, the later being a group of bones which are fused together.

The cervical region is made up of 7 bones, labelled from c1 to c7. It starts from the head downwards. It is also called neck vertebrae. It is small and delicate with eighteen of cervical nerves. The thoracic is made up of 12 bones, labelled from t1 to t12. They are also known as the upper back vertebrae. The lumbar region has five bones, labelled l1 to l5. It can also be called lower back vertebrae. The sacrum and coccyx region are made up of a group of bones fused together, all making up about 30 bones in total.

2.2.2. Spinal Cord

The spinal cord purposely sends neural impulses to and from the brain and to and from other parts of the body. It also has neural circuits that can control various reflexes independently. It receives information from the body and sends it to the brain. It also receives information from the brain and sends it to the various parts of the body. Therefore, it acts as a channel.

It is made up four regions which are the cranial spinal nerve, thoracic spinal nerve, sacral spinal nerve, lumbar spinal nerve, sacral and coccyx spinal nerve.

They are all located inside the vertebrae consisting of the same names. The spinal cord has pairs of nerve roots which bulge out of the ends of each vertebrae.

The spinal cord itself consists of grey and white matter. There is a hole located inside the spinal cord known as the *central canal*. This hole contains a special fluid that helps in nourishing tissues called *cerebrospinal fluid*, which also acts as a shock absorber. It has the *pia matter, dura matter and the arachnoid*, which help in the protection of the spinal cord.

The shape of the spinal cord varies in different regions. It is also part of the central nervous system.

2.2.3. Nerve or Spinal Roots

They are nerves with roots that are attached to the spinal cord. They receive information from the spinal cord which carries information from the central nervous system and they send it into various parts of the body. They also send information from the various parts of

the body into the spinal cord. They act as branches. They are made up in pairs. They are part of the peripheral nervous system.

the spinal nerves consist of a ventral root (front root) and a dorsal root (back root). They later conjoin to form a big spinal nerve.

The dorsal roots contain the ganglion and are always used for sensory neurons. They bring in sensory information to the spinal cord through the dorsal root.

The ventral roots are used for the motor neurons. They bring in information from the brain and carry it out to different parts of the body.

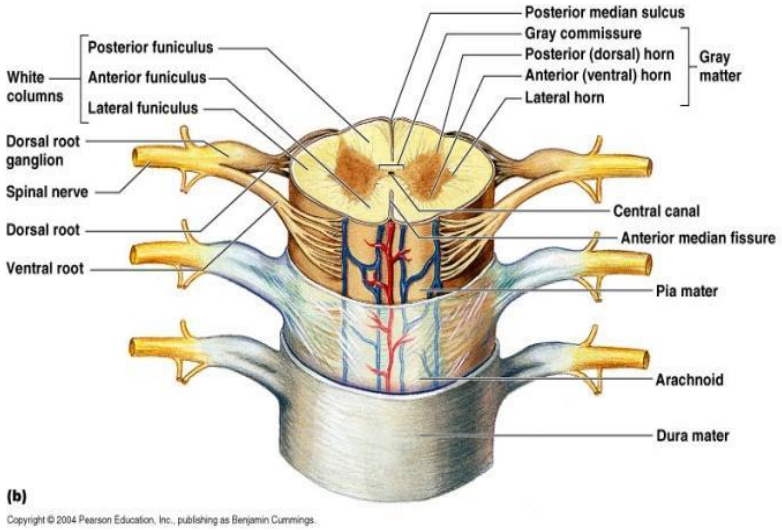


Figure 2.2 Spinal Cord

2.2.4. The Spinal Discs

They are also known as inter vertebral discs. They located in between the spinal bones. They are cartilages made up of soft tissue that act as shock absorbers and aid in mobility of the column. They also act as ligaments that joins and holds the bones together to form the spinal column. Each disc is made up of two parts which are the annulus fibrosis and the nucleus pulposus. The annulus fibrosis has a tough structure. It is made up of special collagen fibres called lamellae. The fibres in the nucleus pulposus have a looser network which is made up of an inner mucoprotenous gel material.

The spinal nerves consist of a ventral root (front root) and a dorsal root (back root). They later conjoin to form a big spinal nerve.

The dorsal roots contain the ganglion and are always used for sensory neurons. They bring in sensory information to the spinal cord through the dorsal root.
There are 23 spinal discs in total found in the vertebral column.

2.2.5. Ligaments and Tendons

They are used to join the vertebrae and keep the bones in place. They also help in reducing wearing when there is motion in the spinal column. Ligaments can restrict excessive movements like hyper-extension or hyper-flexion. Ligaments also prevent movement in particular directions. There are three important ligaments in the spine which are the ligament flavum, posterior longitudinal ligament and anterior longitudinal ligament.
The ligamentum flavum acts as a cover over the dura mater, which is a tissue layer that serves in protecting the spinal cord. It lies under the facet joint. The posterior longitudinal ligament goes upwards and downwards at the posterior part of the spine in within the spinal canal. The anterior longitudinal ligament lies at the front of the vertebra, running up and down the spine.

2.2.6. Shape of The Spine

The spinal column has a certain shape. The cervical region curves slightly inwards. The thoracic region curves outwards. The lumbar region which is also called the lower back is curved slightly inwards. This description is a description of a healthy and well grown spinal column.

2.2.7. Muscles of The Spine

There are four types of vertebral muscles which are forward flexors, lateral flexors, rotators and extensors. The lateral flexors and rotators are found in the lateral location of the spine. The forward flexors are found in the anterior location of the spine, whilst the extensors are located at the posterior region of the spine. They are all under voluntary control and have very fast contraction rate due them being skeletal muscles. Nerve impulses travels form the brain and into the spinal cord, which are then sent to the muscles. Energy is required for the muscle to contract. Mitochondria produces adenosine triphosphate (atp). As mitochondria burn glucose, atp is produced. The blood vessels deliver the nutrients the mitochondria need to provide an adequate supply of atp.

There are numerous muscles located in the spine with specific functions located in specific region. But for this report alone, we would only state the main muscles located at the posterior cervical and upper thoracic spine.

The longissimus cervicus – cervical vertebrae extension

The longissimus capitus – helps in head rotation and also pulls backward

Longisimus thorasis – helps in extension, lateral flexion of the vertebral column

Iliocostalis thoracis – helps in extension and rib rotation

Ilocostalis cervicus – helps in extension of the cervical vertebrae

Semispinalis thoracis – helps in extension and rotation

Semispinalis capitus – helps in extension and rotation

2.2.8 Joints of The Spine

According to the oxford dictionary, a joint is where two or more bones meet. Their purpose is for ease of articulation or motion. The common joints found in the spine are called facet joints. They can also be called *apophyseal joints*. Every bone or vertebra has a pair of facet joints. The superior articular facet faces upwards, while the inferior articular facet faces downwards. There are also joints located on the sides of the vertabra. Facet joints are located at the posterior past of the spine. They behave hinge-like in manner. They are also synovial joints, meaning they are surrounded by a specific type of soft tissue which its sole purpose is to produce a fluid to nourish and also lubricate the joint, which was explained in previous pages. The joints aid in extension, flexion and twisting.

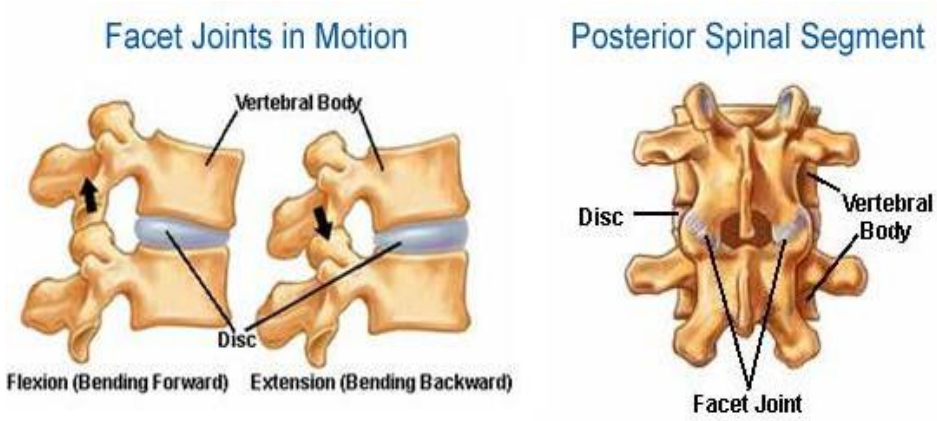


Figure 2.3 Facets joints and posterior spinal segments

2.3. Clinical Significance

2.3.1. Abnormalities

There are several abnormalities of the spine. This can be inherited, occur at a certain age or occur due to a certain environment or habit.

2.3.2. Abnormal Curvature

There are three types of abnormal curvature of the spine which are *lordosis, kyphosis,* and *scoliocis*. Lordosis is a situation in which the lower back is significantly curved inwards. Kyphosis is a situation which the upper back is abnormally rounded (about 50 degrees of curvature). Scoliosis is a situation in which the person's spine looks like a c curve or s curve. There a lot of health issues that causes these problems. Lordosis can be caused by *achondroplasia,* which is a disorder in which there is an abnormal growth of bones, this also causes dwarfism. *Osteoporosis* can also cause lordosis. It is a condition whereby the bones in the spine become very soft, causing it to curve. *Obesity* can also cause lordosis. *Discitis* is the inflammation of the disc that are found between the bones, this causes lordosis as well. Kyphosis can be caused by *arthritis, osteophoresis*, *spina bififda* which is a birth defect. This is when the spinal column of a fetus when developing inside the womb. Other causes are *spine tumors* and *spine infections*. Scoliosis however runs in families, therefore is hereditary.

2.3.3. Common Diseases of The Spine

There are a lot of diseases that occur in the spinal column. In this report we will limit them to a few.

VERTEBRAL COMPRESSION FRACTURES

This happens when the vertebra collapses. The main cause of this is *osteophoresis,* which is a disease that leads to loss of bone density. It can also be caused by different tumors or cancers.

CERVICAL STENOSIS

This is the narrowing of the nerve passageways or spinal canal. It can be called *cervical central stenosis* if the spinal canal is narrowed. It is called cervical *foramenal stenosis* if the

foramen or the sides of the spinal cords are narrowed. Symptoms of this disease include neck pain, weakness, burning sensations, hand clumsiness, numbness in legs, arms and shoulders.

NECK STRAIN

This is one of the most common complaints concerning the spine. They can be caused by a herniated disc or spinal stenosis. These pains can be very severe. Some causes can be a person's habit. For example, sitting on a chair with no support or perhaps holding a handset with your ear and shoulder. Another way of getting severe neck strain is *whiplash*, which is caused by an injury during an accident. There is an excessive flexion and extension of the head during any collision.

CERVICAL MYOLEPATHY

This occurs when there is a compression of the spinal cord in the neck. The symptoms can be very small when it is in its early stage. Some of the symptoms are clumsiness of the hands and arms, changes in handwriting, numbness, difficulty to work with or pick up small objects and difficulty in walking in a stable manner.

DEGENERATIVE SPONDYLLISTHESIS

Spondylolisthesis can be defined as a situation in which a vertebral bone slips forward over another vertebral bone. Degenerative spondylolysthesis is when there are degenerative changes in the bones of the spine. It usually occurs at the lower back. It is very common with old female patients over the age of 61. Some symptoms of degenerative spondylolisthesis are lower back pain, limping irregularly, leg weakness, muscle spasms and tight hamstring muscles. It usually occurs at the fourth and fifth lumbar regions of the spine.

DISC HERNIATION

This disease is the main focus and main purpose of our project. A herniated disc occurs when the outer region of a vertebral disc breaks down. This then causes the inner gel like portion (nucleus pulposus) to leak out. This extrudes to nerves which are located close to the disc, causing an irritation. The spinal disc acts as a shock absorber for the articulating bones of the spine. It is made up o soft tissue. The outer portion (annulus fibrosus) helps in containing the softer inner part of the disc (nucleus pulpolsus). There are two main regions in which the

disc hernia occurs which are the sacral and lumbar regions of the spine. This leads us to the two main types of disc herniation.

- cervical disc herniation

This is disc herniation which occurs in the cervical region(c1-c7). This can cause irritation o the nerve roots located to the discs which are located at the neck region. These nerve roots send information into the arms. Thus, when they get irritated they cause pain to radiate along their path, which is from the spinal cord, to the shoulder and the arms. The two most common levels to herniated are the c5-c6 vertebra and the c6-c7 vertebra. Symptoms of cervical disc herniation include pain in the neck arm, fingers and hands. The pain occurs according to the site or level of the spinal disc affected. Usually, mri scans are taken to diagnose disc hernia, but due to neck pain being so common for other diseases or problems, it takes an amount of time to diagnose this condition.

-Lumbar disc herniation

This is disc herniation which occurs in the lumbar region. It is located at the lower back region. In this case, the weak spot in the outer region lies directly under the spinal nerve roots. Disc herniation then puts pressure on the nerve roots located in that particular area. The nerve roots will then extend pain down the legs. The most common symptom for this is leg pain, which is also known as sciatica. Most of the disc herniation that occurs in the lumbar region occurs in the l4-l5 and l5-s1 regions. Some other symptoms are weakness when raising the big toe and numbness of the foot. This can also be diagnosed using mri scan but takes an amount of time to determine if it is lumbar disc herniation because many other diseases have the same symptoms with disc hernia.

2.3.4. Causes of Disc Herniation

It most likely occurs due to a gradual wear. Therefore, it is mostly age related and occurs to older people. The spinal discs loose water content as they age making them less flexible and causing them them to rupture. Another cause of disc herniation is lifting heavy weight objects. Also, a fatal accident like a traumatic fall or a hard hit in the back can cause disc hernia, but this rarely happens.

2.3.5. Symptoms of Disc Herniation

One sided pain and numbness of one part of the body

Pain occurs in mostly arms and legs.

Pains becomes worse during the night or when carrying out a particular activity.

Pains become worse after sitting or standing.

Burning sensations, tingling or aching of the area affected.

Weakness of the muscle**.**

2.3.6. Factors of Disc Herniation

These are the risk factors of disc herniation:

Age – occurs to people at a much older age.

Weight – obesity can cause extra stress on the spinal discs at the lower back.

Genetics – some people inherit a mutation which makes them liable to develop disc herniation.

Occupation – people with jobs that are physically demanding like weight lifting, or lifting objects are liable to have a lot of back pain. These weight lifting can cause disc hernia.

2.3.7. Complications of Disc Herniation

In complicated cases, saddle anesthesia, bladder and bowel dysfunction can occur.

2.3.8. Diagnosis of Disc Herniation

Disc herniation can be diagnosed by different methods:

Magnetic resonance imaging (mri) – this is the most common method used to diagnose disc hernia. Detailed images of the spine are created using radio waves and magnetic pulses. Using the pictures, we can point the area of the disc affected.

Computerised tomography (CT) – we take a series of pictures of cross sectional images of the spine.

Discogram – a dye is used in this method. The dye is injected into the soft part of several discs. Then we use them to determine the defected disc.

Myelogram – a dye is used here as well. It is injected into the spinal fluid. Then, it is x-rayed.

2.3.9. Treatment of Disc Herniation

With adequate treatment, it is possible to get fully relieved form this condition. There are three ways in which disc herniation can be treated.

Medication

Nerve pain medications, narcotics, over the counter medication, muscle relaxants, epidural injections.

Surgery

This is only considered when therapy and medications are not successful. The protruding portion of the disc is removed; this is called open disectomy. The second option is removing the whole spinal disc. Then it is replaced with metal supports.

Therapy

Physical therapists aid patients to help them minimize the pain caused by the disc. The therapist may recommend an ultrasound or electrotherapy. They might also recommend traction, treatment with heat, treatment with ice and short term bracing for the lower back or cervical region in order to improve support.

CHAPTER3

NEURAL NETWORKS

3.1 Introduction

Artificial neural networks inspired of the architecture of the human brain are designed to create artificial intelligence similar to human. Neurons as the basic processing units and connections among them are the main elements in artificial neural networks.

Today neural networks have found their applications in a wide range of fields such as power engineering, telecommunications, image processing, 3d modeling, finance, management and etc. Biomedical engineering as an interdisciplinary field with a tremendous progress in recent decades can benefit from neural networks to solve many different problems. Data fitting, data clustering and pattern classification are fundamental affordable tasks by neural networks in different fields.

3.2. Medical Diagnosis Using Artificial Neural Network

Using the artificial neural networks for medical diagnosis is a very effective method for improving performance and deep learning to comfort medical processes.

This method covers:

- artificial intelligence
- artificial neural network
- diagnosis disease
- heart disorders
- intelligent medical diagnosis
- neural network optimization
- swarm intelligence

For example, for diagnosis part, neural network is used for detection of cancer and heart problems.

3.3. Neural Network Applications:

Neural networks have been applied very successfully in the width spectrum of data intensive applications, such as:

- financial neural network (e.g. Credit rating, price forecast, property appraisal…)
- medical neural network (e.g. Diagnosis, patient's length of stay forecasts…)
- industrial neural network (e.g. Process control, quality control…)
- science (e.g. Chemical compound identification, pattern recognition…)
- sale and marketing (e.g. Sale forecasting, targets marketing …)
- data mining (e.g. Prediction, classification, knowledge discovery…)
- operational analysis (e.g. Cash flow forecasting…)
- hr management (e.g. Staff scheduling, personal profiling…)
- energy (e.g. Electrical load forecasting, energy demand forecasting…)

3.4. Architecture of Neural Networks (ANN)

Figure 3.1 depicts a single processing unit in an artificial neural network where p inputs $x_1 \dots x_p$ and a bias value are entered to the processing unit to result the output o. The main task in developing a neural network is to determine the weight values $w_{j,1} \dots w_{j,p}$ and the bias value x_0 in such a way to lead to the output value after passing the transfer function f. This task is referred to as training. So in a neural network both the bias value and weights are adjustable. The created network can then be used to predict the output value of other inputs or classify the inputs. As previously discussed in this work we aim to develop a neural network which will assist to classify a data base of patient's information into either normal or affected based on several factors.

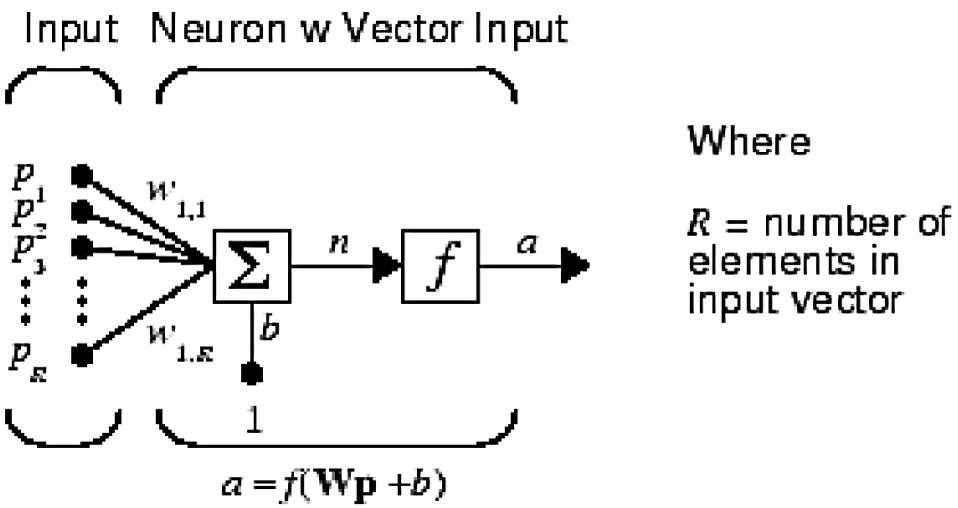


Figure 3.1 Processing unit in a neural network (Neuron)

As expressed by the following equations in a neuron the weighted summation of the inputs added by the bias value will pass a special function called transfer function or activation function to result the output *an* of the neuron.

$$n = w_{1,1}\, p_1 + w_{1,2}\, p_2 + \ldots + w_{1,R}\, p_r + B$$

$$n = \boldsymbol{W}\boldsymbol{p} + b$$

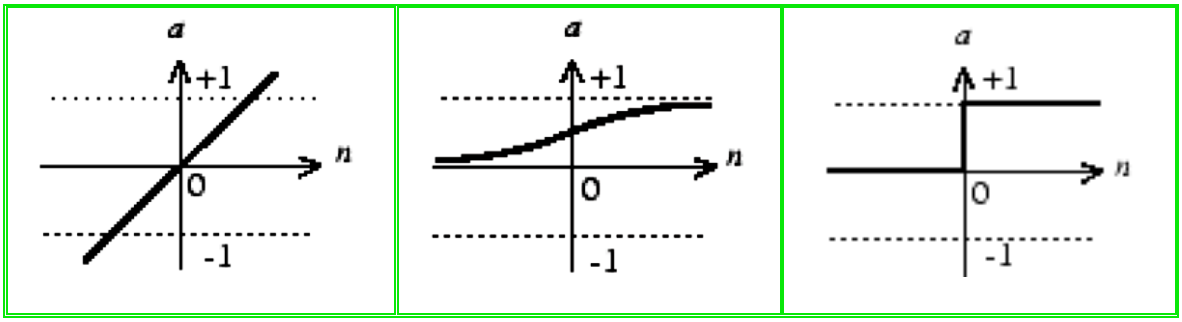
$$a = f(\boldsymbol{W}\boldsymbol{p} + b)$$

3.4.1. Transfer Function

There are many different types of transfer functions and the selection of the suitable function for a neuron depends on the situation of the neuron in a neural network and also on the purpose of using the network. For example, neurons with a linear transfer function are usually used in final layers of networks with several layers called multilayer neural networks. These types of neural networks are widely used to approximate a function. As another example sigmoid functions are often used as the transfer function in neurons of hidden layers of multilayer networks.

The following table provides the graphs of the three mostly used transfer functions.

Matlab neural network toolbox includes also many other transfer functions.



3.4.2. Neural Network Creation

The processing units of neural networks can be combined in many different ways to create various types of neural networks. Feedforward ann and recurrent ann are the two mostly used neural networks however the fast evolution of neural networks and their huge applications in many different areas has led to an increasing list of them.

As illustrated in figure 3-2 *r* processing units or in another word *r* neurons can be gathered to form a layer of neurons. All inputs enter to each neuron with different bias values and after passing the transfer function will produce an output value *a*.

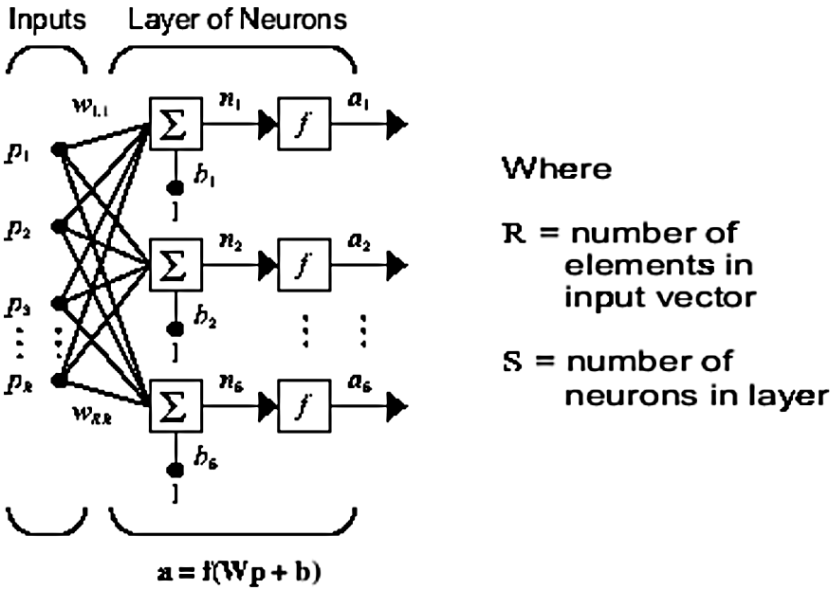


Figure 3.2 A layer of neurones

Several layers of neurons can then be serially connected to produce a multilayer neural network which is quiet powerful. The selection of suitable transfer function for each layer is a crucial task which enables the network to approximate any function.

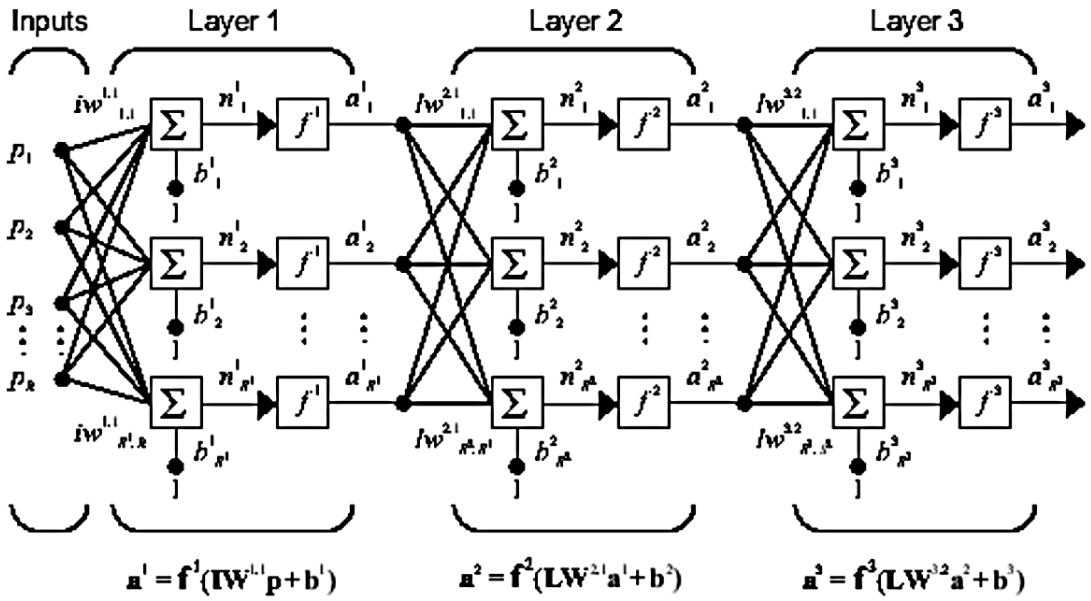


Figure 3.3 Multi layer neural network

3.4.3. Neural Networks Input Data Structure:

When developing a neural network in matlab the inputs will enter the network in the form of a vector or multiple vectors. Generally, the inputs can enter the network either simultaneously that are referred to as concurrent input to develop a static network or sequentially in time to form a dynamic neural network.

In the present work we develop a static neural network which will work as a classifier.

The input data are some real data (numbers) representing parameters related to disk hernia. The data are collected from a public database available on the internet: uci learning machine.

3.5 Neural Network Development:

Once the input and output values of a network are determined the following steps are done to develop the neural network.

3.5.1 Initializing Weights:

The first step before training a network is to determine an initial value for the weights and bias. In matlab the ‘init’ command will initialize the network but the ‘train’ function which is used to train networks already include the initialization step of the network inside.

3.5.2 Training a Neural Network:

As previously explained in neural network architecture the main step of designing a neural network is to determine the weight values in such a way to reach the closest value to the output and when the weights are determined the trained network can be used to predict the output of some new input data.

Reaching the closest value to the output can be achieved using an optimization algorithm. This process is done by a performance function. The default performance function in matlab is the mean square error.

$$F = mse = \frac{1}{N}\sum_{i=1}^{N}(e_i)^2 = \frac{1}{N}\sum_{i=1}^{N}(t_i - a_i)^2$$

The above function calculates the mean squared error value between the network output and the target value. The calculated error will be then propagated backward in the network to assist in updating the weights using the optimization algorithm.

3.5.3. Validation

The training step will be executed iteratively to decrease the error and the process can be stopped by the number of validations which can be determined by the user or by a previously determined magnitude of error.

3.5.4 Testing

Once the network is trained and validated it can accept any arbitrary input to calculate the correspondent output. We can use a part of our data base that we already know the result to make sure if the network is working precisely. This step is usually referred to as testing the network.

CHAPTER 4

PROPOSED SYSTEM

4.1 Automatic Disc Hernia Diagnosis

In this project, we aim to develop an algorithm which will be able to diagnose disc hernia, using six biomechanical features obtained from the patient and run through a neural network. These six features will be discussed in a later part of this section and how the algorithm works with a neural network (which has already been discussed in the previous section).

4.2 Methodology

The method for this approach includes obtaining of data from the patient, this data can be obtained by running an x-ray of the spinal cord region of the patient and in doing this six features are of interest to us which are derived based on the shape and orientation of the pelvis and lumbar spine.

The six biomechanical features used for these network are; pelvic incidence, pelvic tilt, lumbar lordosis angle, sacral slope, pelvic radius and grade of spondylolisthesis.

Next, these data are fed into the network and compared to data which the network has already been trained to recognise and the data is normalised, using back projection.

Finally, the network produces an output for the patient, based on two categories; normal or disk hernia.

4.3.1 Pelvic Incidence

In the human spinal cord, there is a line perpendicular to the sacral plate and there is another line which connects the midpoint of the sacral plate to the bicoxofemoral axis. The angle that exists between these two lines is the pelvic incidence.

A normal pelvic incidence angle for adult according to a study is 53 ± 9^{o}.

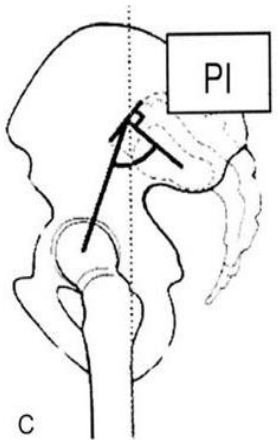


Figure 4.1 Pelvic incidence

4.3.2 Pelvic Tilt

The pelvic tilt of humans refers to the position of the pelvis in relation to the thigh bone and the rest of the body.

A natural pelvic tilt differs between humans but is usually between 10-13 degrees between the thigh bone and the rest of the body, but the pelvis can tilt towards the front, back or either side of the body which in turn changes the angle of the tilt and causes an abnormality.

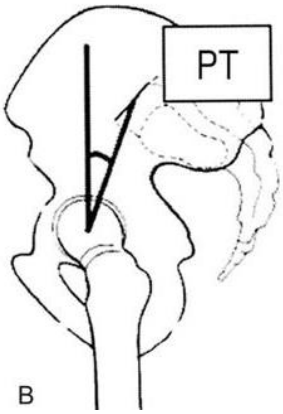


Figure 4.2 pelvic tilt

4.3.3 Lumbar Lordosis Angle

This refers to the angle formed by the inward curve of the lumbar and cervical regions of the spine.

This curve is present in all humans, but there is a widely acceptable range of angle for this inward curve and for the purpose of this project, we are using the range acceptable for adults between the age of 30-50 years which lies between 33.2 ± 12.1^{o}.

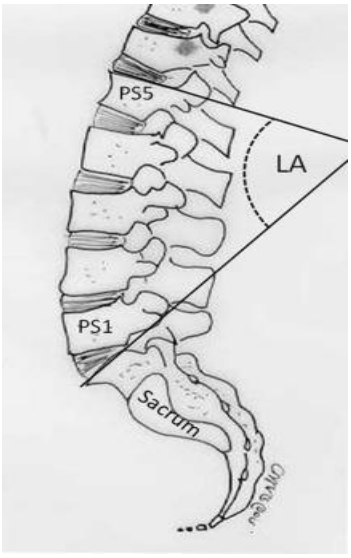


Figure 4.3 lumbar lordosis

4.3.4 Sacral Slope

The sacral slope is defined as the angle which is between the sacral plate and a line taken horizontally.

As all values of parameters differ from human to human for the purpose of this project the normal angle for an average adult age of 47 years is 40-50^{o}.

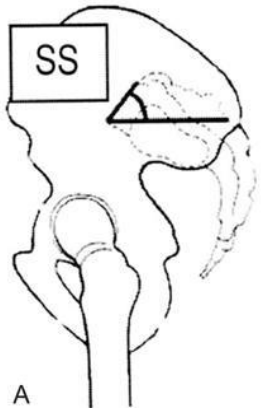


Figure 4.4 sacral slope

4.3.5 Pelvic Radius

The pelvic radius is a measurement which is taken in relation with the sacral slope. It is the sum of the sacral endplate slope and the fixed pelvic contribution to lordosis.

The normal pelvic radius for adults of an average age of 45 years is about 90-110^{o}. This value can change for a different age group.

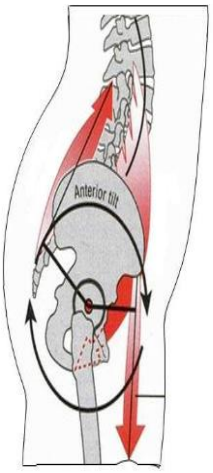


Figure 4.5 pelvic radius

4.3.6 Grade of Spondylolisthesis

The grade of spondylolisthesis refers to how far forward a vertebral bone has slipped forward, compared to another.

There are five grades, according to how far forward the bone has slipped, with grade 1 being the least slip and grade 5 the most slipped. These grades are shown on the table below;

Table 4.1. Grade of spondylolisthesis

Grade 1	25% of vertebral body has slipped forward
Grade 2	50% of vertebral body has slipped forward
Grade 3	75% of vertebral body has slipped forward
Grade 4	100% of vertebral body has slipped forward
Grade 5	Vertebral body completely fallen off (i.e.,spondyloptosis)

4.4. Proposed Neural Networks as Pattern Classifier

Neural networks have strong performance in pattern recognition and classification. In this work the previously discussed input data from pelvic x ray images of 310 patients with six different items and the correct classification as normal or abnormal are known.

As our data base containing information of only 310 patients is not so large we have chosen to use 70% of the data base to train our network. 15% is used to validate the system and the rest for testing. The network is developed on matlab platform r2015a using neural network toolbox.

4.4.1 Determining Input and Output Vectors

Input data derived from the uci website are fed to the network as a matrix of size 6×310 where each column contains the 6 biomedical information of each patient.

The target of the network is also defined as a vector of size 2×310 with only zero or one elements. In the case of normal disk, the corresponding element for each patient in the first row is set to zero and in second row is set to one and for disk hernia affected patients the corresponding element in first row is set to one and in second row is set to zero.

4.4.2 Network Creation

The neural network we are using as classifier is a feedforward neural network with tangential sigmoid as transfer function is hidden layers and a normalized exponential function as the transfer function of the output layer. The neural network with this architecture is proved to have a satisfactory performance for pattern recognition and classification problems.

The following figure illustrates the created network. As for each input vector there are two target values the output layer has two output neurons. We have also set the number of hidden layers to ten which seems to be suitable for our network where the number of neurons is not so high.

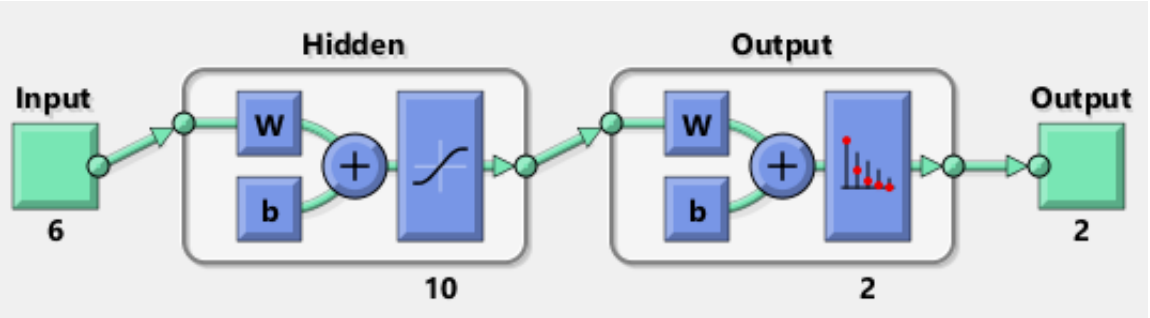


Figure 4.6 Created Neural network

4.4.3 Data Division Set Up

In this step the data base is randomly divided for training, validation and testing purposes.

4.4.4 Network Training

After determination of the input and target data for training the network these data will be used to train the network. Network training procedure is already explained in chapter 3.

The ‘train’ function in Matlab is used to train the network.

While the network is getting trained the following window is displayed on Matlab representing the neural network parameters and the training progress.

In our system the training procedure has stopped after 23 iterations with six validation checks.

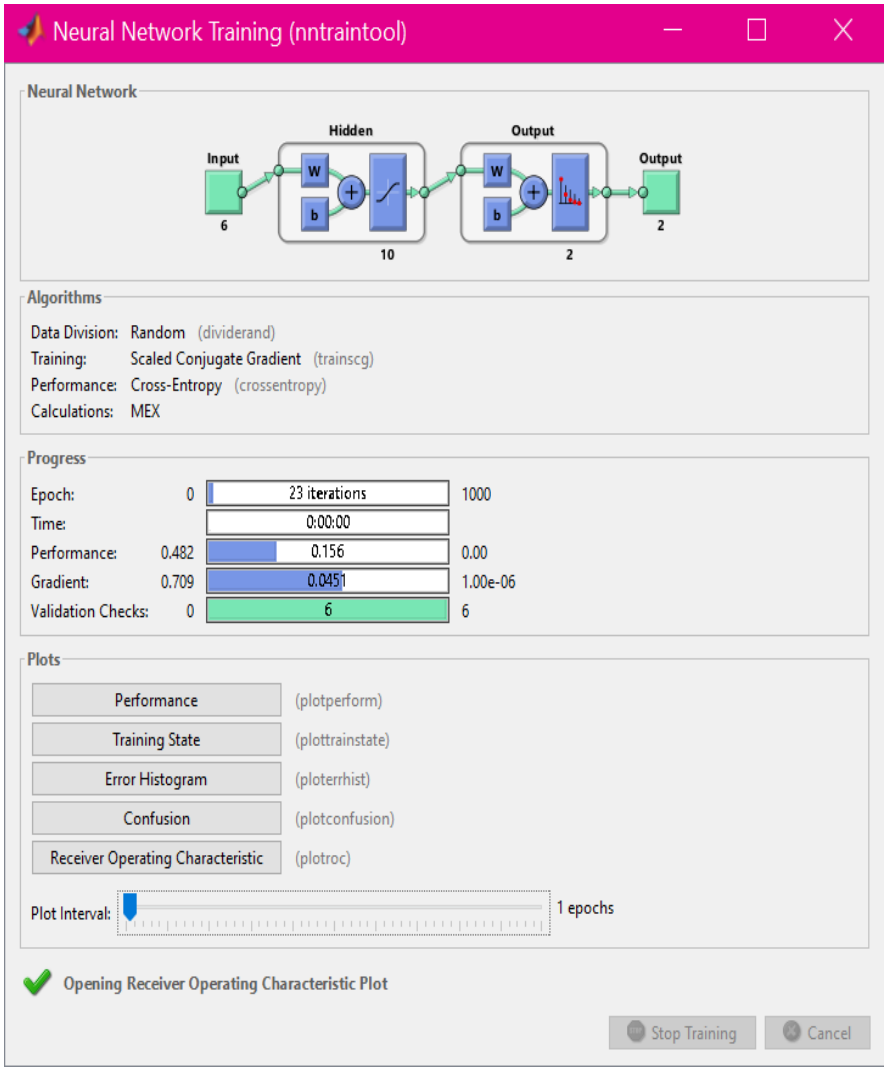


Figure 4.7 Network training window on MATLAB

4.4.5 Testing The Network

When the training procedure is stopped the network is ready to compute the output for any given input. We will feed 15% of randomly chosen inputs from our data base where we already know the correct output to test our network and evaluate its performance.

4.4.6 Performance Evaluation

The following figure depicts the confusion matrices for the training, validation, testing steps and a combination of all data. Green squares contain the number and the percentage of correct responses and the incorrect responses are provided in red ones. We can see that number of correct responses are rather high which proves the acceptable performance of our network.

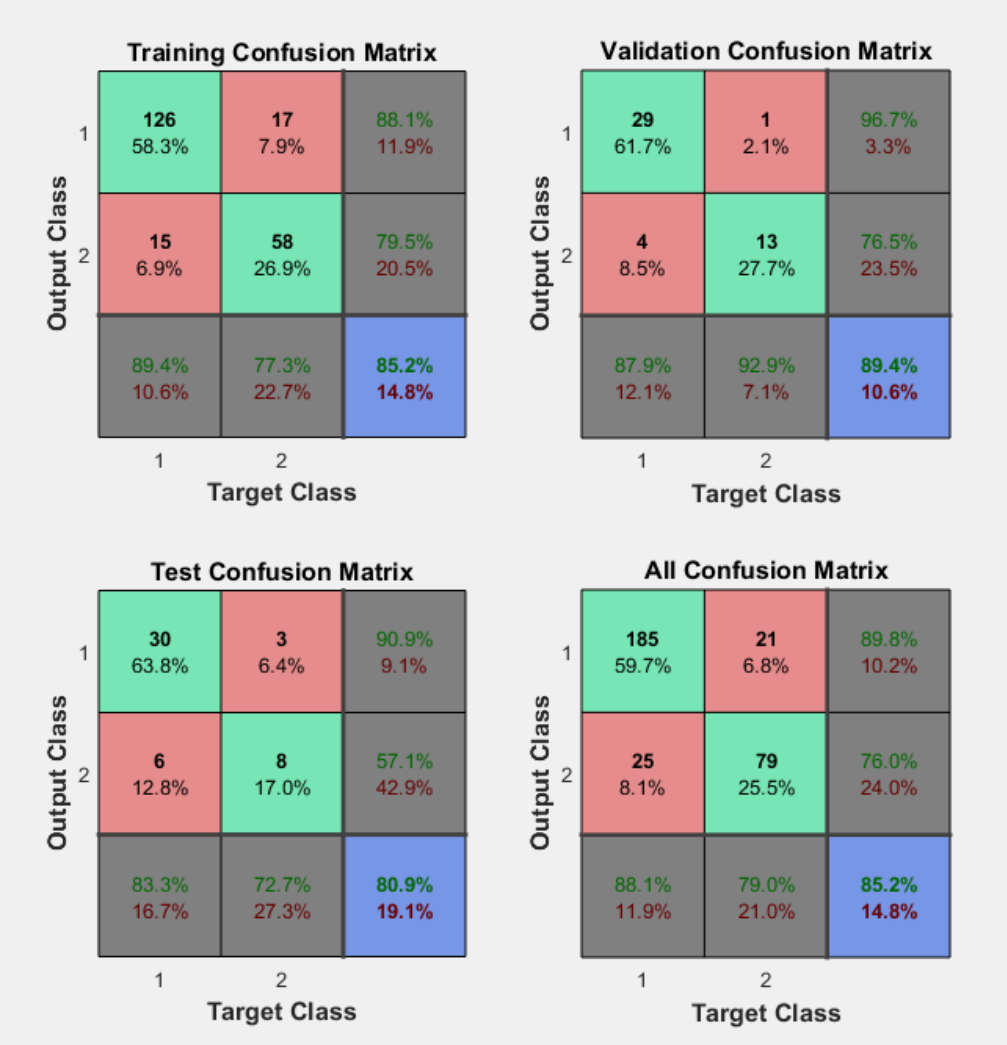


Figure 4.8 Confusion Matrices

The test, validation and testing performance of the network are illustrated on the following figure.

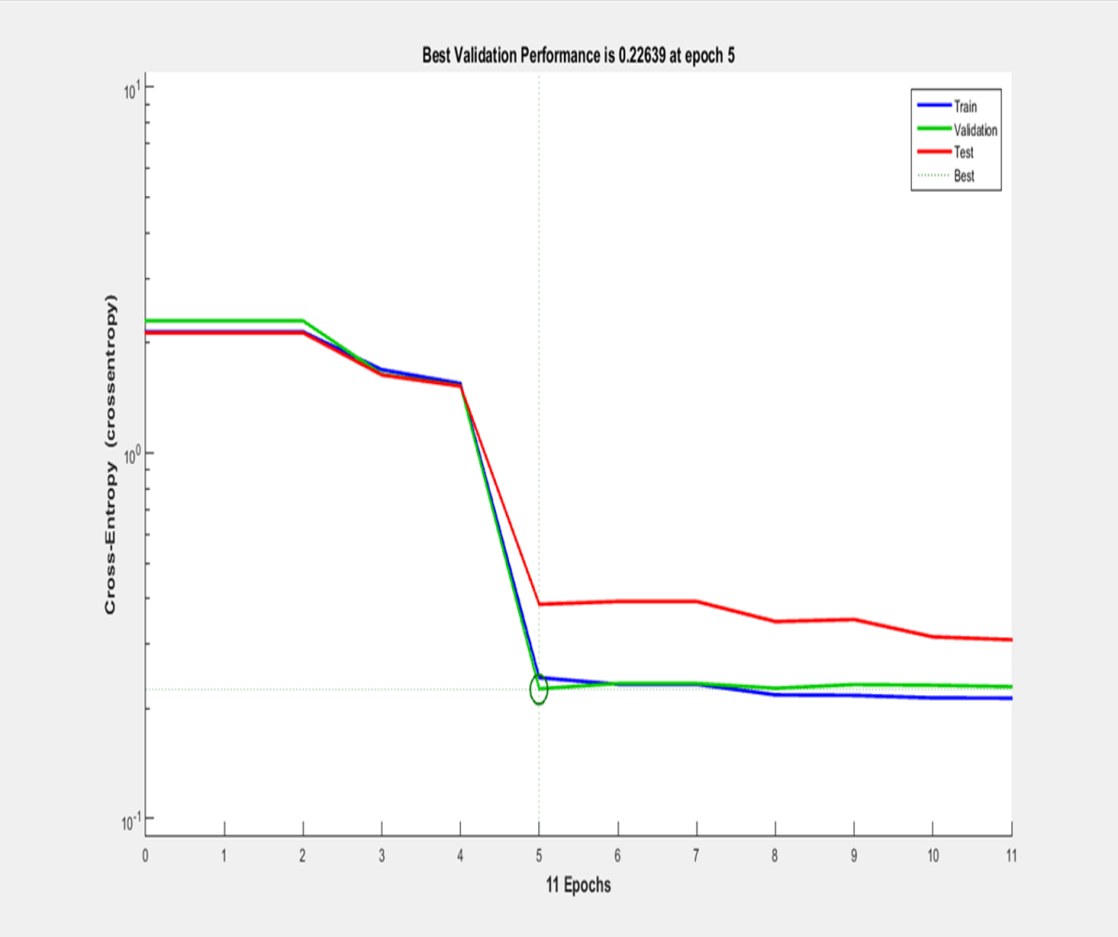


Figure 4.9 Validation performance

This graph also proves the acceptable performance of our network as the final cross-entropy is pretty small. The characteristics of error for test set and validation set are similar and by the 17th iteration where the best validation performance occurs there is no significant overfitting.

4.5 Performance of The Program

Our project is an algorithm which automatically diagnoses disk hernia using the six biomechanics features (discussed in the above section) and neural network.

We have trained the network to recognise and classify patients into normal and abnormal (disk hernia), based on the six features. Below is a table which shows our result.

TABLE 4.2. Performance of program

State of patient	Number of patients	Number of working data	Percentage of working data (%)
Normal	210	185	59.7%
Abnormal (Disk hernia)	100	79	25.5%
Total	310	264	85.2%

The data used above and for this project was gotten from the university of california irvine database, which is a trusted center for machine learning and intelligent systems.

It is without doubt that the project still needs some development in order to improve the diagnoses of disk hernia, this is just the first part of the final project, subsequently, we will improve this project so that it can have near perfect and trustworthy results for the diagnoses of disk hernia.

Also, the time taken to run this algorithm and produce a final output is of utmost importance to us. One of the aims of this program is to save as much time as possible. Although our program is still in the early stages of development, below is a table of functions used in the algorithm and the time it takes to complete each function;

4.6. Profile Summary:

Table 3. Profile summary

Function	**Time taken (s)**
Data	0.150
Inputs	0.002
Targets	0.003
nnetParam>nnetParam.fieldnames	0.001
nnetParam>nnetParam.isempty	0.004
nnetParam>nnetParam.nnetParam	0.040
nnetParam>nnetParam.struct	0.003
nnetParam>nnetParam.subsasgn	0.001
nnetParam>nnetParam.subsref	0.002
nnetParamInfo>fcn2filename	0.032

4.7. Future Aspects

We cannot overemphasize the fact that this project and the algorithm is still in the early and developmental stages, it is our aim to improve this project as a whole to be able to recognize and diagnose disk hernia automatically. The network should be able to load and accept patient data, process this data and produce an output which will classify this patient into either a normal or abnormal class.

So far, we are training the network to be able to recognise patterns and to know which combination of data or biomechanical values constitute a normal result and which does not.

CONCLUSION

This network and the algorithm used will help in the automatic diagnosis of disk hernia automatically, as can be seen from the performance table and learning curve, has a high accuracy value (85.2%).
It is our aim to develop a program which works almost 100 percent and can give reliable and trustworthy result for disk hernia detection.

As interests in the field of disc hernia increases, more data will become available, which in turn will widen the scope of training for the network. This development is sure to increase the accuracy of the network in classifying the results.

Keywords

Hernia: a condition in which part of an organ is displaced and protrudes through the wall of the cavity containing it.

Cervical: relating to the neck.

Vertebrae: each of the series of small bones forming the backbone, having several projections for articulation and muscle attachment, and a hole through which the spinal cord passes.

Gray matter: the darker tissue of the brain and spinal cord, consisting mainly of nerve cell bodies and branching dendrites.

White matter: the paler tissue of the brain and spinal cord, consisting mainly of nerve fibers with their myelin sheaths.

Cerobro-spinal fluid: clear watery fluid which fills the space between the arachnoid membrane and the pia mater.

Pia mater: the delicate innermost membrane enveloping the brain and spinal cord.

Dura mater: the tough outermost membrane enveloping the brain and spinal cord.

Arachnoid: a fine, delicate membrane, the middle one of the three membranes or meninges that surround the brain and spinal cord, situated between the dura mater and the pia mater.

Pulposus: inner core of the vertebral disc. The core is composed of a jelly-like material that consists of mainly water, as well as a loose network of collagen fibers. The elastic inner structure allows the vertebral disc to withstand forces of compression and torsion.

Lamellae: a thin layer, membrane, or plate of tissue, especially in bone.

Mucoprotein: any of a group of various complex conjugated proteins (as mucins) that contain glycosaminoglycans (as chondroitin sulfate or mucoitinsulfuric acid) combined with amino acid units or polypeptides and that occur in body fluids and tissues.

Flavum: refers to the ligament that connects the vertebrae of the spine and provides stability for posture and spinal movement. The word “flavum” is derived from the latin “flavus,” or yellow, which is the color of a ligamentum flavum.

Synovial: relating to or denoting a type of joint which is surrounded by a thick flexible membrane forming a sac into which is secreted a viscous fluid that lubricates the joint.

Flexors: a muscle whose contraction bends a limb or other part of the body.

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APPENDICES

THE CODE

```
>>DATA=LOAD('DATA NAME.FORMAT'); % THIS LOADS THE DATA.
>>INPUTS = DATA(:,1:6); % THIS READS THE DATA IN THE SPECIFIED ROWS.
>>INPUTS=INPUTS'; % THIS TRANSPOSES THE DATA.
>>TARGETS = DATA(:,7:8); % THIS READS THE DATA IN THE SPECIFIED ROWS.
>>TARGETS =TARGETS'; % THIS TRANSPOSES THE DATA.
>>HIDDENLAYERSIZE = 15; % SPECIFIES THE NUMBER OF HIDDEN LAYERS IN THE NETWORK.
>>NET = PATTERNNET(HIDDENLAYERSIZE); % SPECIFIES THE PATTERN OF THE HIDDEN LAYERS.
>>NET.DIVIDEPARAM.TRAINRATIO = 70/100; % SPECIFIES THE DATA TO BE USED FOR TRAINING.
>>NET.DIVIDEPARAM.VALRATIO = 15/100; % SPECIFIES THE DATA TO BE USED FOR VALIDATION.
>>NET.DIVIDEPARAM.TESTRATIO = 15/100; % SPECIFIES THE DATA TO BE USED FOR TESTING.
>>NET.TRAINPARAM.EPOCHS = 5000; % SPECIFIES THE NUMBER OF ITERATIONS.
>>[NET,TR] = TRAIN(NET,INPUTS,TARGETS); % COMBINES THE VARIABLES TO PRODUCE OUTPUT.
>>OUTPUTS = NET(INPUTS); % SPECIFIES THE OUTPUT.
>>ERRORS = GSUBTRACT(TARGETS,OUTPUTS); % CONSIDERS THE ERROR CONTAINED IN THE DATA.
>>PERFORMANCE = PERFORM(NET,TARGETS,OUTPUTS); % FOR THE PERFORMANCE OF THE NETWORK.
>>VIEW(NET) % TO VIEW THE RESULT.
```