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Automatic osteoporotic vertebral fracture analysis and identification by dual energy x- ray absorptiometry

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Contents

<i>Acronyms and Abbreviations</i>	6
Introduction	9
1.1 Project Background	9
1.1.1 Fracture	9
1.2 Problem Description	10
1.3 Project Objectives	10
1.4 Project Scope	10
Literature Review	11
Requirements	17
3.1 How existing system works	17
3.2 Requirement Specifications	17
3.2.1 Functional Requirements	17
3.2.2 Non-Functional Requirements	18
3.3 Use Case Diagram	18
Design	23
4.1 System Architecture	23
4.2 Activity diagram	24
4.3 Sequence Diagram	24
4.4 Deployment Diagram	25
4.5 Data flow Diagram	26
4.6 Package Diagram	27
System Implementation	28
5.1 Tool and technologies	28
5.1.1 Visual Studio 2013	28
5.1.2 Emgu CV	28
5.2 Languages	28
5.3 Dataset	28
5.4 Methodology	29

5.3.1	Image Sharpening	30
5.3.2	Segmentation	31
5.3.3	SURF Algorithm	33
5.3.4	Fracture classification	33
System Testing and Evaluation		35
6.1	Software Testing Technique	35
6.1.1	Function Testing	36
6.1.2	Performance Testing	36
6.3	Test Cases	36
Conclusion		41
References		42

List of figures

Figure 2.1 Imaging techniques of spine for detection of VFs.....	12
Figure 2.2Dual energy x-ray absorptiometry of the spine.....	13
Figure 2.3 Vertebral fracture assessment by DXA showing mild fracture of L1 vertebral body..	14
Figure 2.4: Reference data for MXA and MRX.	15
.Figure 2.5 Vertebral fracture assessment using a semiquantitative technique, J. Bone Miner..	16
Figure 3.1: Main use case Diagram.....	19
Figure 3.2: use case 1.....	20
Figure 3.3: use case 2.....	20
Figure 3.4: use case 3.....	21
Figure 3.5: use case 4.....	22
Figure 4.1 Context Diagram.....	23
Figure 4.2 Activity Diagram.....	24
Figure 4.3 Sequence Diagram.....	25
Figure 4.4 Deployment Diagram.....	26
Figure 4.5 Data flow Diagram.....	27
Figure 4.6 Package Diagram.....	27
Figure 5.1: Dataset Images.....	29
Figure 5.2: Block diagram.....	30
Figure 5.2: Image sharpening results.....	31
Figure 5.3: Training image.....	32
Figure 5.4: Segmentation of vertebrae.....	33
Figure 5.4: An example of type of fractured vertebrae of a patient.....	34
Figure 5.5: Fracture type detected by system of each vertebra.....	34
Figure 6.1: Accuracy Graph.....	41

List of tables

<i>Table 2.2 WHO criteria for defining bone density</i>	12
<i>Table 3.1 Use Case table</i>	19
<i>Table 3.2 Use Case1 table</i>	20
<i>Table 3.3 Use Case2 table</i>	21
<i>Table 3. 3 Use Case3 table</i>	21
<i>Table 3.4 Use Case3 table</i>	22
<i>Table 5.1: Dataset Images for Training and Testing</i>	29
<i>Table 6.1: Test Case 2</i>	37
<i>Table 6.2: Test Case 3</i>	37
<i>Table 6.3: Test Case 4</i>	38
<i>Table 6.4: Test Case 5</i>	38
<i>Table 6.5: Test Case 6</i>	39
<i>Table 6.6: Test Case 7</i>	39
<i>Table 6.7: Test Case 8</i>	40
<i>Table 6.8: Test Case 9</i>	40
<i>Table 6.9: Test Case 10</i>	41

CERTIFICATE

It is to certify that the final year project of BS (CS) “**Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiometry**” is developed by “**TAYYABA FAISAL**” under the supervision of “**DrSumairaKausar**” and that in her opinion; it is fully adequate, in scope and quality for the degree of Bachelors of Science in Computer Sciences.

HEAD OF DEPARTMENT

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INTERNAL EXAMINER

EXTERNAL EXAMINER

Acronyms and Abbreviations

DXA	Dual Energy X-ray absorptiometry
VFA	Vertebral Fracture Assessment
BMD	Bone Mineral Density
IVA	Instant Vertebral Assessment
SURF	Speeded-Up Robust Features
SIFT	Scale-Invariant Feature Transform

ABSTRACT

Vertebral column plays a vital role in the human body, which protects the spinal cord, gives hardening to the body and connects muscles of the human body. Human vertebral also transmits body weight in strolling and standing, but under a few conditions, human vertebral fracture occurs which cause damage in the progression of the vertebral bone. Vertebral fractures mainly occur due to injury or disease that weakens the bones and have a high impact on human health. Osteoporosis, is the most common disease to cause a vertebral fracture. Osteoporosis increases the risk to sustain a vertebral fracture and debilitate the vertebral column without any major indications. Osteoporosis is not diagnosed with conventional radiography techniques until 20 - 40 % of bone mass has been lost. Vertebral fractures are classified as wedge, biconcave, or a crush fracture. This system "Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiometry" is basically a desktop application which is mainly targeted for hospitals and medical laboratories where Instant Vertebral assessment is done by dual energy x-ray absorptiometry. This application will not only reduce the workload of technicians performing tests but also of patients who has to wait for the reports for a long period of time. The application is made in such a way that a technician who wants to detect vertebral fracture not only can perform the test but can also view the results by detecting fracture types of lumbar spine vertebrae.

Chapter 1

Introduction

1.1 Project Background

Human vertebral column is vital part of human body. The vertebral column is a bony, segmented structure extending from neck to tail which is part of the axial skeleton, made of a series of bones which are known as vertebrae. The major function of the vertebral column is to protect the spinal cord, it additionally gives hardening to the body and connects pectoral and pelvic supports and muscles of human body. Human vertebral also transmits body weight in strolling and standing

1.1.1 Fracture

A bone fracture is a clinical condition in which there is a damage in the progression of the bone. Fractures are result of stretch, disease that weaken the bones. As vertebral is one of the most essential part of human body but under some circumstances vertebral fractures occur few of them are discussed below:

- **Osteoporosis**

Osteoporosis is a disease of bones which makes them brittle and frail due to low density in bones, which increases risk to sustain a vertebral fracture. It influences more in women than in men happening most regularly in older people. Osteoporotic patients have no symptoms until bone fractures occur. Key hazard elements for osteoporosis are genetics, lack of exercise, calcium and vitamin D, personal history of fracture as an adult, smoking, history of rheumatoid arthritis and low body weight [1].

- **Injury**

Injury in vertebral column, occur when vertebrae break and collapse, due to injury or harm, such as encountering a terrible fall or car accident. Vertebral breaks might be brought on by simple movements like coughing or sneezing if vertebrae have turned out to be frail and fragile due to osteoporosis

- **Pathologic fracture**

Pathologic fracture is a fracture occurring in the vertebra due to preexisting disease at the fracture site. A bone breaks in an area that is weakened by another disease process. Reasons for weakened bone incorporate osteoporosis, tumors, contamination, and certain acquired bone issue. There are dozens of diseases and conditions that can lead to a pathologic fracture.

But in this system only osteoporotic vertebral fractures will be identified.

Osteoporotic vertebral are hard to which influence the vertebral body and are often only discovered when the vertebral is clinical analyzed by dual energy x-ray absorptiometry (DXA)[2]. Vertebral is analyzed by scanning thoracolumbar spine at a resolution of 1-0.35 mm with Hologic Discovery. X-ray absorptiometry scanner use Instant Vertebral Assessment scan option to scan the spine .This evaluation of vertebral decide if deviations in the size and shape of vertebrae are due to fractures or are simply non-fracture deformities.

Further, depending on the fracture morphology, fractures are categorized into three types: concave, wedge and crush.

1.2 Problem Description

This project investigates automated diagnosis of osteoporotic vertebral fracture by using the image processing techniques.

Osteoporosis is a common bone disease which can cause fractures. These fractures are hard to diagnose and are often only discovered when vertebral is imaged. Vertebral is clinically analyzed by scanning thoracolumbar spine at a resolution of 1-0.35 mm with Hologic Discovery. X-ray absorptiometry scanner use Instant Vertebral Assessment scan option to scan the spine. [3]

Contrary to traumatic fractures, osteoporotic fractures generally influence the vertebral body. Depending on the fracture morphology, fractures are classified into three types: concave, wedge and crush.

The main challenge encountered at assessment of the vertebral is to determine whether deviations among the size and structure of vertebrae are due to actual fractures or non-fracture deformities [4], which are due to variation in size of vertebral

1.3 Project Objectives

To design an automatic osteoporotic vertebral fracture analysis and identification from vertebral fracture assessment by dual energy x-ray absorptiometry

1.4 Project Scope

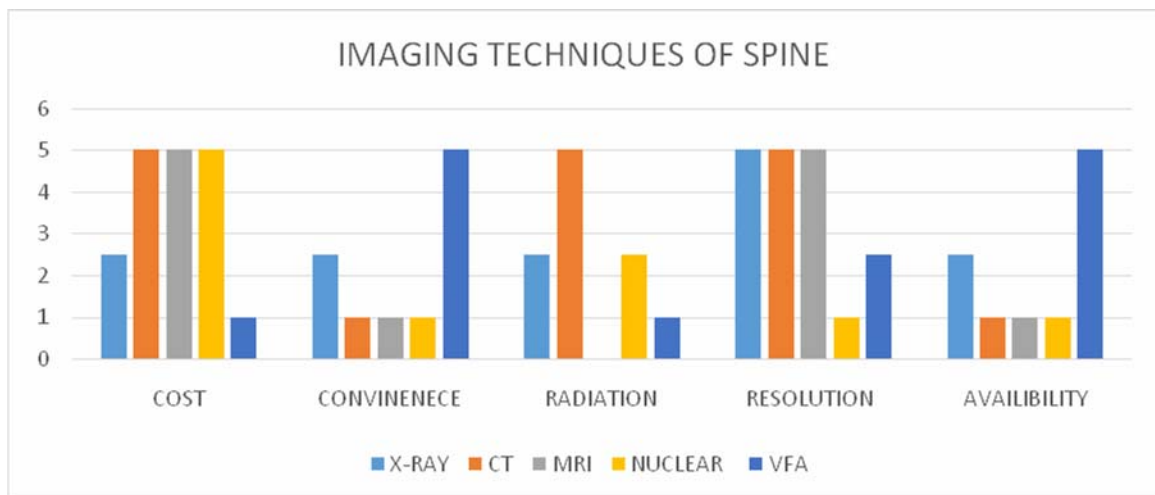
In an automatic vertebral fracture analysis and identification system an input image of vertebral fracture is assessed by dual energy x-ray absorptiometry to identify fracture in a human vertebral and identify fracture type: concave, wedge and crush.

Chapter 2

Literature Review

Osteoporotic vertebral are hard to which influence the vertebral body and are often only discovered when the vertebral is clinical analyzed by dual energy x-ray absorptiometry (DXA)[2].Vertebral is analyzed by scanning thoracolumbar spine at a resolution of 1-0.35 mm with Hologic Discovery. X-ray absorptiometry scanner use Instant Vertebral Assessment scan option to scan the spine .This evaluation of vertebral decide if deviations in the size and shape of vertebrae are due to fractures or are simply non-fracture deformities. Further, depending on the fracture morphology, fractures are categorized into three types: concave, wedge and crush

E. Michael Lewiecki and Andrew J. Laster [1] state thatvertebral fractures are the most common type of fragility fractures which are not diagnosed easily. They are related including tremendous malady then mortality and increase risk of fracture, independently over bone mass density. Recognition of vertebral fractures with the aid of imaging of the spine may additionally alternate a patient's diagnostic classification, fixity regarding fracture risk, and onset because of pharmacological intervention. Treatment regarding sufferers include vertebral fractures reduces the chance over after fractures, even when the measure of bone mass density is upon the osteoporosis diagnostic cut point concerning -2.5 . Vertebral fracture analysis diagnose vertebral fractures with higher affected person convenience, less radiation exposure, yet decrease cost than standard backbone radiography.[1]



5: HIGH

2.5: MEDIUM

1: LOW

0: NONE

Figure 2.1 Imaging techniques of spine for detection of VFs

Thus, none of diagnostic methodology meets all of the criteria but it is concluded that vertebral fracture assessment (VFA) is more convenient in terms of cost and availability.

Low bone mass density and micro architectural deterioration of bone tissue, are major causes of osteoporosis. Main sites for osteoporotic fractures include human vertebrae, the hip, the forearm. RICHARD BRUNADER, M.D., and DAVID K. SHELTON [2] in a research regarding evaluation of osteoporosis by radiologic bone assessment discussed some major causes of osteoporosis, low bone mass density (BMD) has been proven highest risk factor for fragility fracture. Thus World Health Organization (WHO) defined osteoporosis by bone mineral density (BMD) measurement and T score (statistical measure of bone mass density that best correlates with fracture risk and is based on values derived from DXA) as its standard for defining BMD. Following are some results for bone density. Osteoporosis is not detected with mostly diagnostic technologies until 20 to 40 percent of BMD has been lost.

Condition	T-score range
normal	-1.0 and above
osteoporosis	-2.5 and below
severe osteoporosis	-2.5 and below with a fracture
osteopenia	between -1.0 and -2.5

“Information from Assessment of osteoporotic fracture risk and its application to screening for postmenopausal osteoporosis. Report of a WHO Study Group. World Health Organ Tech Rep Ser 1994;843:1–129”

Table 2.2 WHO criteria for defining bone density

Dual energy x-ray absorptiometry is the most widely used technique for measuring bone mass density (BMD).

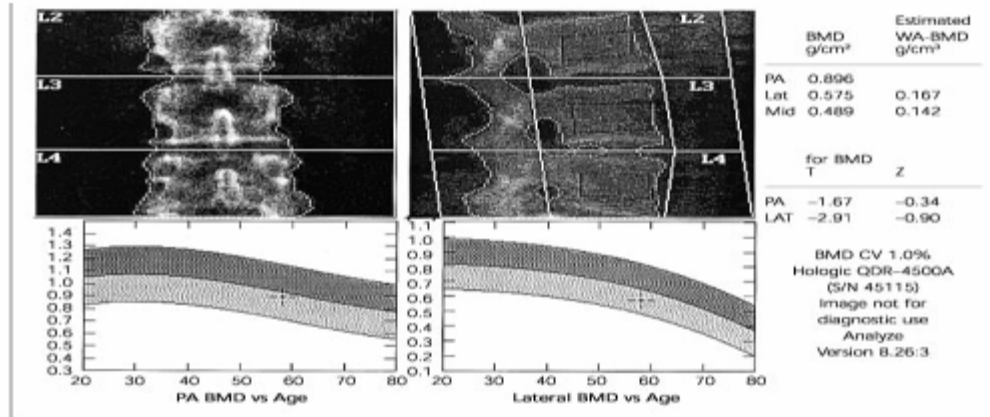


Figure 2.2

Dual energy x-ray absorptiometry of the spine, (left) posterior (PA) and (right) lateral views. Views of L2 through L4 with associated regions of interest. Notice that the PA view includes posterior cortical elements, and the lateral view T score is lower, thus being more sensitive for osteoporosis. The respective curves for age are also shaped differently, because of increasing degenerative changes that overlap on the PA view. Notice that the patient's PA T score is -1.67, while the lateral T score is -2.91 standard deviations below peak young normal levels.

Sides where T score is lower are being more sensitive for osteoporosis. In above results patient's T score is below peak young-normal levels.

James F. Griffith [3] discussed diagnosis and appropriate cure over vertebral fracture at an early stage minimize the risk of future fracture as well as reduced patient pain and deformity. Effective way to deal with perform spinal radiographs, increased awareness and a high level of observer involvement in image interpretation are keys to the reliable identification and reporting of vertebral fractures.

A vertebral fracture is analyzed when there is 20% or more misfortune in expected vertebral body stature. A few non-fractures vertebral deformations exist that may lead to distortion of vertebral fracture by an inexperienced. Semi-quantitative (SQ) analysis is the best technique to utilize both in the clinical and research setting though quantitative vertebral morphometry can be complimentary to SQ in large longitudinal trials. X-ray is able to diagnose vertebral fracture with greater sensitivity than other imaging techniques and can help determine fracture age as well as distinguish osteoporotic from neoplastic fracture.

DXA is widely utilized to measure bone mineral density. DXA machines which unite fan pillar innovation and appropriate software which allow the acquisition of modest resolution images of the thoracic and lumbar spines to help identify vertebral fractures. Imaging vertebral fractures using DXA is known as vertebral fracture analysis (VFA).



Figure 2.3 Vertebral fracture assessment by DXA showing mild fracture of L1 vertebral body

Vertebral fracture assessment by DXA showing mild fracture of L1 vertebral body. DXA, dual energy X-ray absorptiometry. VFA can be performed in the meantime as bone densitometry with a parallel and frontal image of the spine. The vertebral bodies caudal to T7 can be routinely surveyed while those amongst T7 and T4 are not consistently observed. The advantages of VFA over radiography are convenience, less radiation, low cost. Joining common vertebral fracture status with BMD improves fracture risk prediction of both vertebral and non-vertebral fracture.

In this review [4] the identification of prevalent vertebral deformities are analyzed but not incident vertebral deformities. The utility of morphometric appraisal of common vertebral distortions utilizing MXA compared with conventional radiographs.

Acquiring the lateral images of the spine required for vertebral morphometry this, technique is termed as morphometric X-ray absorptiometry (MXA). In spite of all extraordinary understanding in analyzable vertebrae, particularly for immediate and genuine deformities, the natural issue of the image quality of MXA scans depletes the number of vertebrae analyzed adequately for analysis. Hence the number of deformities identified, particularly in the upper thoracic spine.

Regardless of the fact that MXA image quality is plainly substandard as compared to that of standard radiographs, MXA has advantages such as substantially reduced effective dose to the patient, securing of a solitary photo of the spine, and the expulsion of the nonlinear cone-beam-induced amplification intrinsic in traditional radiography. These advantages make MXA a potentially useful, relatively fast, low-radiation technique to distinguish prevalent vertebral

deformities, in conjunction with morphometric radiography in some patients. It will depend on the requirements of any particular study or clinician whether an MXA scan has the capability to fulfil the role required.

Predominant vertebral deformations are related with a considerably increased risk of ensuing vertebral and non-vertebral fractures. Learning of vertebral fracture status is a critical part in the prediction of further breaks in patients with osteoporosis.

The scans and radiographs were analyzed by trained observers utilizing six focuses to evaluate the state of each vertebral body. From these focuses, three vertebral statures were measured as foremost, center, and back. Deformity identification by MXA was constrained as a result of poor picture quality, essentially in the upper thoracic spine. One in six MRX deformations were missed by MXA as they happened in vertebrae not pictured adequately for investigation on the MXA scans. Deformation identification was poorer in the upper thoracic spine in analyzable vertebrae with an affectability of 50% for MXA as MRX. In spite of the fact that MXA picture quality is indifferent as compared to that of regular radiographs. MXA is a conceivably helpful, generally quick, low-radiation strategy to recognize common vertebral deformations, especially direct to extreme distortions in the thoracic and lumbar spine, in conjunction with morphometric radiography in a few patients.

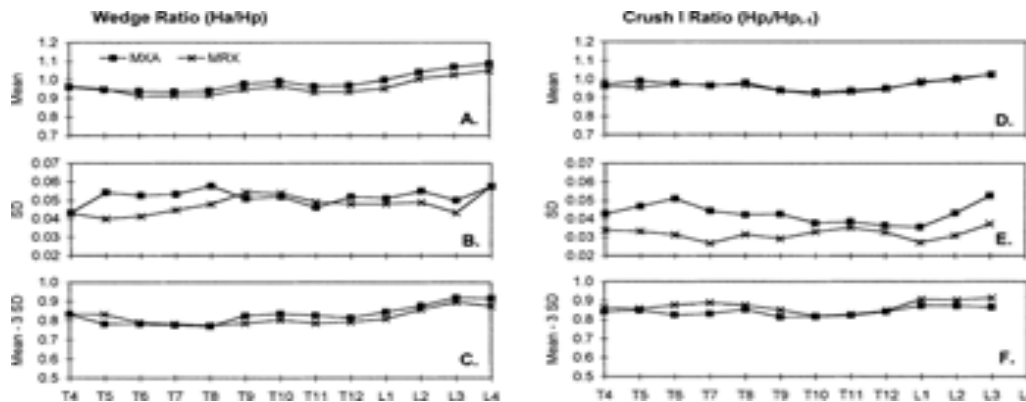
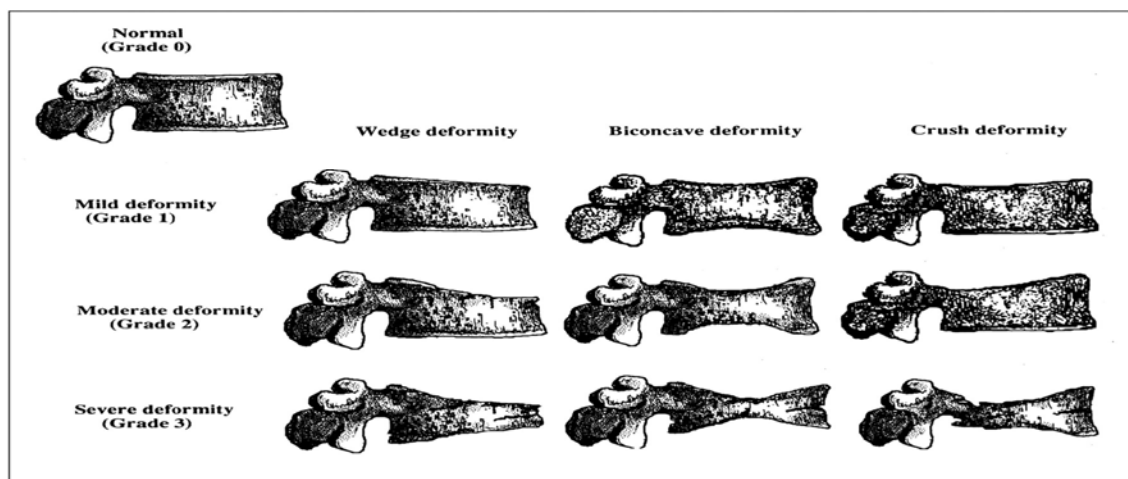


Figure 2.4: Reference data for the wedge ratio (H_a/H_p) for MXA and MRX. (A) Mean; (B) SD; (C) deformity threshold—mean less 3 SD. Reference data for the crush I ratio ($H_{p_i}/H_{p_{i-1}}$) for MXA and MRX. (D) Mean; (E) SD; (F) deformity threshold—mean less 3 SD

Osteoporosis is a highly common condition, bringing about critical morbidity and mortality. In any case, it is usually, untreated. Diagnosing vertebral fractures, which are frequently not clinically evident, is fundamental to diagnosing osteoporosis and helps to predict the risk of future fractures, predicts the danger of future breaks, and may change the choice of pharmacotherapy. Radiographic, CT, or MRI may additionally describe suspected deformations and differentiate a true fracture from non-fracture deformities. A non-fracture deformities can counter interpretation and evaluation for vertebral fractures. The expansion of lateral spine imaging technology to the densitometer for VFA represented a major progression in the ability to analyze vertebral fractures and osteoporosis. Some characteristics make VFA an ideal

technology to assess for vertebral fractures are: the capacity to obtain the image in the meantime as the DXA is performed, at a lower cost, and essentially bring down radiation measurement than with spine radiography make VFA the ideal and initial imaging methodology to screen for and distinguish vertebral fractures. VFA is profoundly imaging tool to enhance osteoporosis diagnosis and fracture prevention. Prior to evaluating the VFA for fractures, the image should be reviewed to verify the correct patient, guarantee legitimate situating proper positioning was used, and to diagnose any uninterpretable vertebrae or artifacts. While various techniques, for example, qualitative, quantitative morphometric, and ABQ assessment can all be utilized to analyze vertebral fractures, the Genant semi-quantitative strategy is the preferred initial method with a possible addition of ABQ for grade 1 fractures. The Genant semi quantitative strategy joins a subjective approach of investigating the vertebral to decide whether a vertebra is fractured with a quantitative evaluation of review and kind of fracture .Fractures are characterized as wedge, biconcave, or a crush fracture. Wedge fracture is defined as reduction in the anterior to posterior height ratio whereas biconcave is reduction of the mid- to posterior vertebral height ratio, and a crush fracture is reduction of the anterior, mid, and posterior heights compared to that of the vertebrae above or below.



.Figure 2.5 Adapted from H.K. Genant, C.Y. Wu, C. van Kuijk, M.C. Nevitt, Vertebral fracture assessment using a semiquantitative technique, J. Bone Miner.

Given the possibility to predict future fractures, all vertebrae should be assessed to abstain from missing any fractures. Serial VFA pictures can be utilized to diagnose episode vertebral fractures and analyze reaction to treatment when relevant. In equivocal fractures, or different gentle vertebral deformities, when there is a past filled with or doubt for malignancy, and when the acuity of the fracture should be resolved, the supplier can consider an extra imaging methodology to better assess vertebral anatomy [5].

Chapter 3

Requirements

This chapter details the requirement specifications of the project. The proposed project aims to provide an automated osteoporotic vertebral fracture analysis and identification by DXA. User will upload a DXA image, which will be analyzed by a computer program and finally, detect if each vertebra in vertebral column is fractured or is non-fracture deformed.

The proposed project is a desktop application. The purpose of the proposed project is to develop an efficient, reliable and accurate diagnostic tool which will reduce the work load of radiologists by automating the test. The intended automated system will help the practitioners in an efficient detection of osteoporotic vertebral fractures. Non-medical personnel can be trained to use the system and provide details of scoring to the experts for further assessment. Developing an automated version of osteoporotic vertebral fractures, will allow an instant detection of patients and only suspected cases can be referred to the clinical radiologists for an expert examination.

3.1 How existing system works

Osteoporosis is a common bone disease. It can lead to fractures with vertebral fractures occurring most frequently in older people. These fractures are difficult to diagnose and are often only discovered when the spine is imaged. So experts can diagnose vertebral fracture by imaging techniques as spinal X-ray to determine whether a vertebra has collapsed, CT scan to provide detail of the fractured bone and the nerves around it or MRI scan to show greater detail of nerves and nearby discs.

3.2 Requirement Specifications

3.2.1 Functional Requirements

Following are the functional requirements of the system.

3.2.1.1 FUNC_R#1 (Start application)

Start the application

3.2.1.2 FUNC_R#2 (Input)

Input VFA image to system

3.2.1.3 FUNC_R#3 (Choose Files)

User must be able to choose file from storage units through File Manager

3.2.1.4 FUNC_R#4 (View the result)

View the result according to analysis of image.

3.2.1.5 FUNC_R#5 (Close application)

Close the application

3.2.2 Non-Functional Requirements

The non-functional requirements of the system are following.

3.2.2.1 Reliability: The application should reliably analyze vertebrae of each vertebral column so that the overall result reflects a true picture.

3.2.2.2 Security: The system will limit access to authorized users

3.2.2.3 Performance: The system should be efficient and analyze osteoporotic vertebral fractures without any noticeable delay by the users.

3.2.2.4 Maintainability: The system needs to be cost-effective to maintain.

3.2.2.5 State Maintenance: Backup copies of different versions of the system should be kept to avoid any accidental loss of data.

3.2.2.6 Availability: The system does not require any Internet connectivity and will be available once the application has been installed on a desktop

3.2.2.7 Correctness: The system should provide all the functionalities as they are stated in requirements.

3.2.2.8 Usability: System is a single user application which should be simple, clear and self-explanatory so it can be used by any ordinary people and it shouldn't require any training for using the system.

3.2.2.9 Reusability: The systems should be developed in a way that it would ensure high reusability in enhancement of the application in future or reuse of modules in any other related future projects.

3.2.2.10 Efficiency: This application should be efficient regarding speed as well as memory usage. It should be fast enough to satisfy expectations of the users. It should have less response time and be quick in completing the tasks.

3.3 Use Case Diagram

Use cases help to understand how user will do task. Each use case shows different functionality of system.

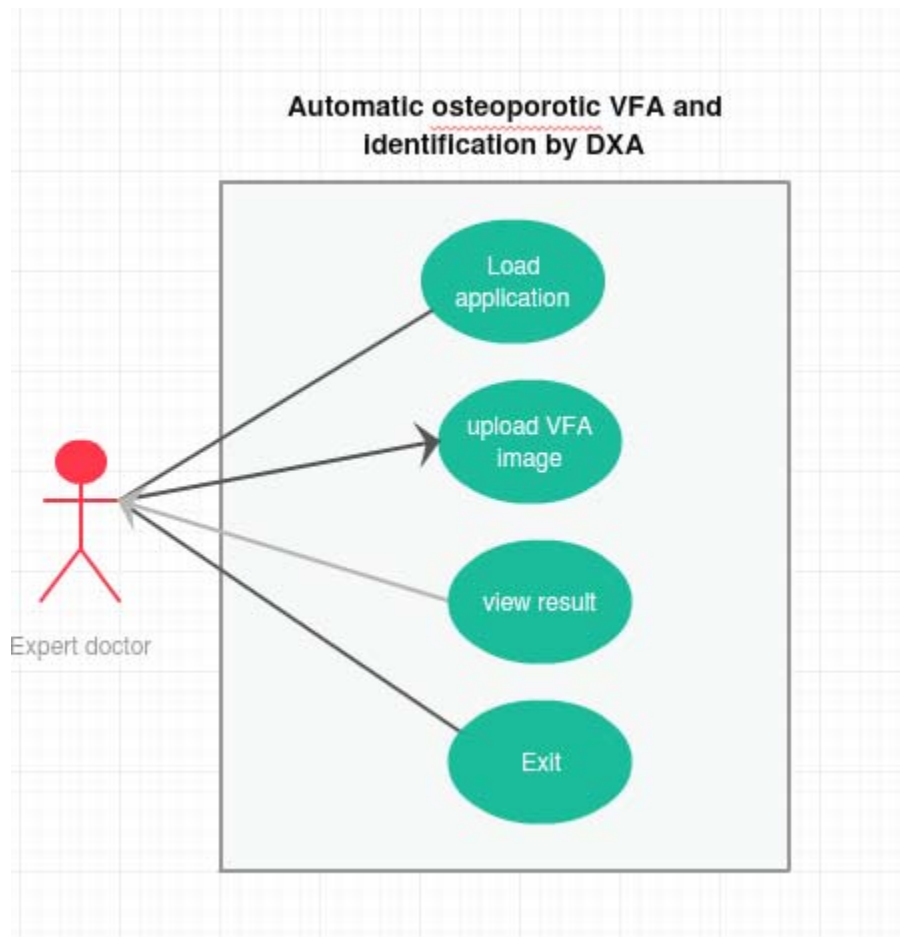


Figure 3.1: Main use case Diagram

Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiome	
Actors	Expert doctor
Description	An expert doctor upload a DXA image, which will be pre-processed by the sys and will identify osteoporotic vertebral fracture
Data	DXA image
Stimulus	User command issued by doctor.
Response	Identify osteoporotic vertebral fracture
Comments	Expert doctor must have appropriate security permissions to access the pa information and the system.

Table 3.1 Use Case table

Use cases of different components of system shown below, starting from figure 3.2 till figure 3.4 and accompanied with table 3.2 till 3.4

Use Case # 1:

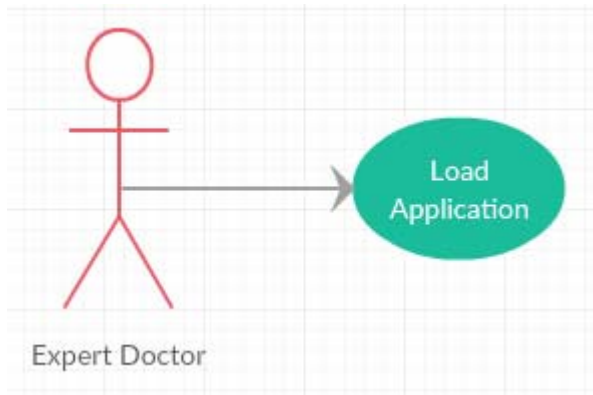


Figure 3.2: use case 1

Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiome	
Use Case Id	UC_1
Title	Load Application
Description	Application will load in users system.
Primary Actor	Expert doctor

Table 3.2 Use Case1 table

Use Case # 2:

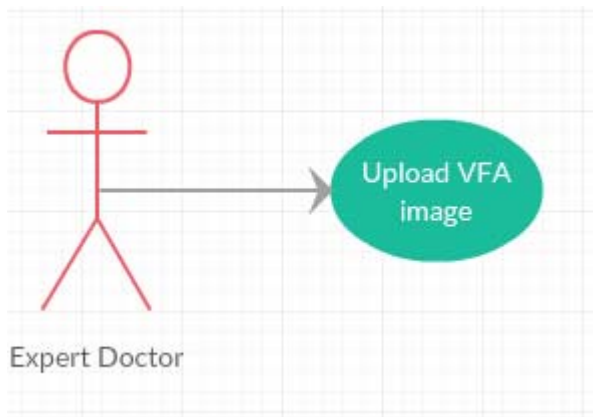


Figure 3.3: use case 2

Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiome

Use Case Id	UC_2
Title	Upload VFA image
Description	Upload VFA image from users system to detect fracture
Primary Actor	Expert doctor

Table 3.3 Use Case2 table

Use Case # 4:

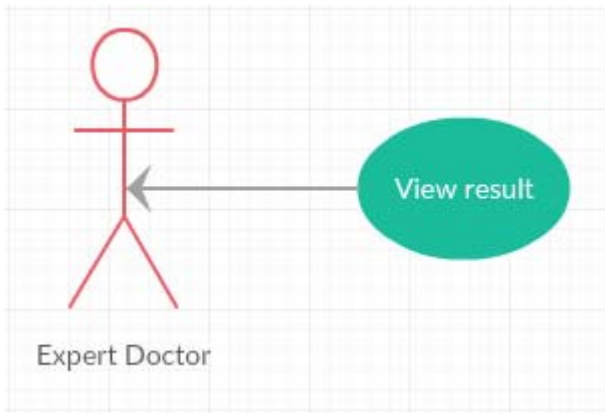


Figure 3.4: use case 3

Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiome

Use Case Id	UC_3
Title	View result
Description	Result is displayed
Primary Actor	Expert doctor

Table 3. 3 Use Case3 table

Use Case # 4:

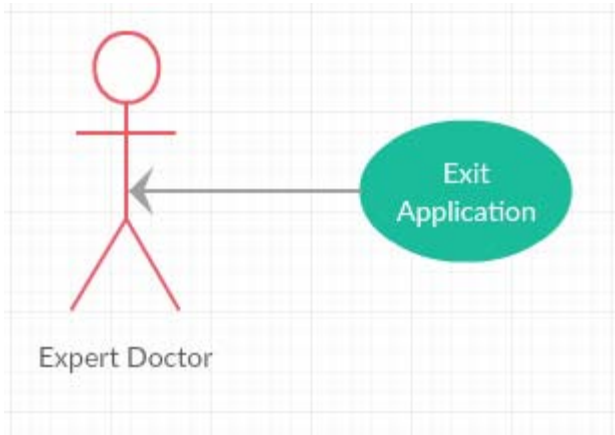


Figure 3.5: use case 4

Automatic osteoporotic vertebral fracture analysis and identification by dual energy x-ray absorptiome

Use Case Id	UC_4
Title	Exit application
Description	Exit application after use
Primary Actor	Expert doctor

Table 3.4 Use Case3 table

USER REQUEST	SYSTEM RESPONSE
Start application	Application will start
Upload VFA image	User must be able to choose file from storage units through File Manager
To detect fracture	Analyze VFA image within sometime

Chapter 4

Design

In this chapter we are going to discuss the design and architecture of the project and overview of how different processes will carry out.

4.1 System Architecture

This desktop application which is intended to be developed has very simple architecture design.

First proposed system will get the vertebral fracture analysis (VFA) image of patient and then process on the image by using C# API's(OpenCV) to detect fracture on vertebrae on vertebral column.

Below is the context diagram showing the boundary of the proposed system, entities their interaction, and its environment.

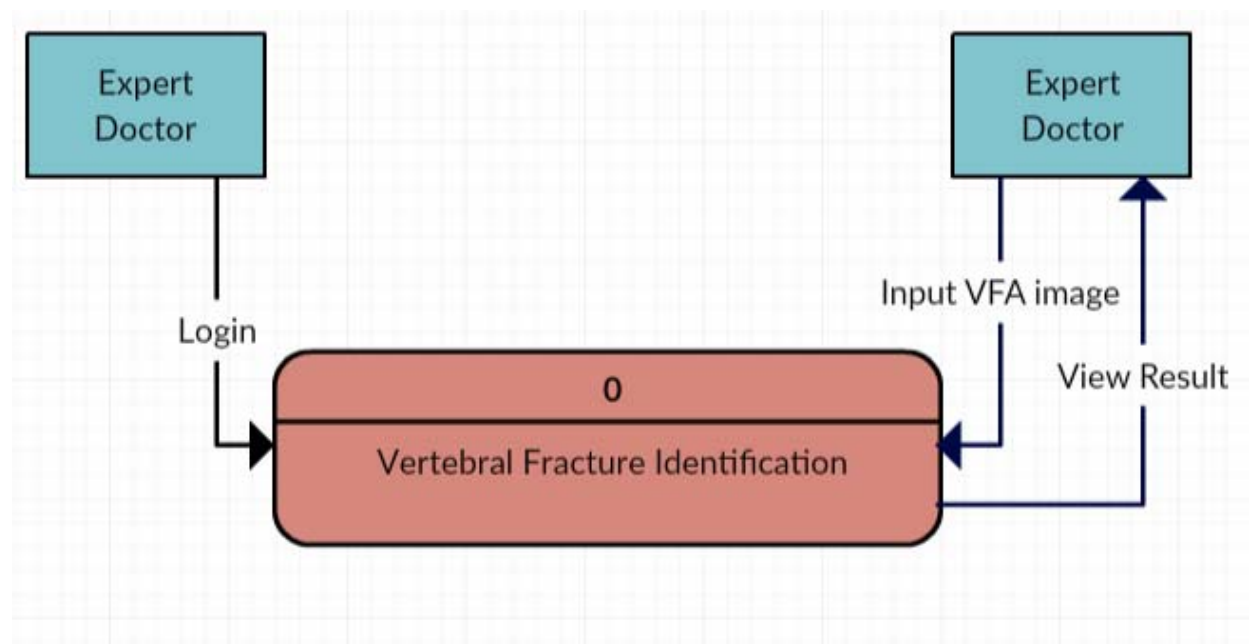


Figure 4.1 Context Diagram

Context diagram show the bird eye view of the system in which user upload VFA image and in the response system provide condition of each vertebra in vertebral column i.e. fractured or to the user.

4.2 Activity diagram

Activity diagram shows the sequence of activities. User will login to system, upload VFA image, system will preprocess the image to enhance features then segment each vertebra of vertebral column to detect fracture. Then result will be displayed.

Below is the activity diagram which shows the flow of activities among different processes.

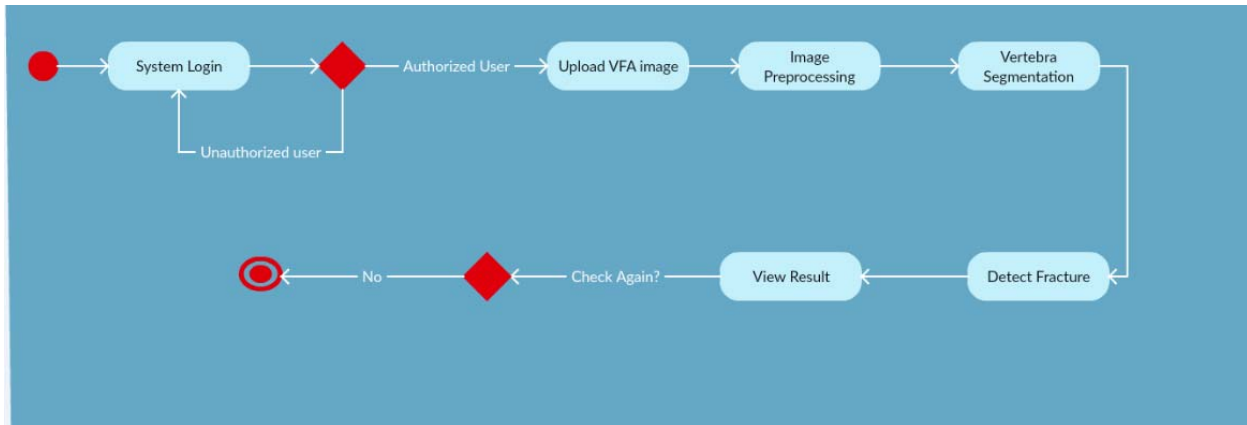


Figure 4.2 Activity Diagram

4.3 Sequence Diagram

The following sequence diagram shows how the process interacts with each other and in what order.

When the user login to system, then upload VFA image which can be preprocessed to enhance features if required, then image will be analyzed which will segment each vertebra of lumbar spine and detect fracture type of each vertebra

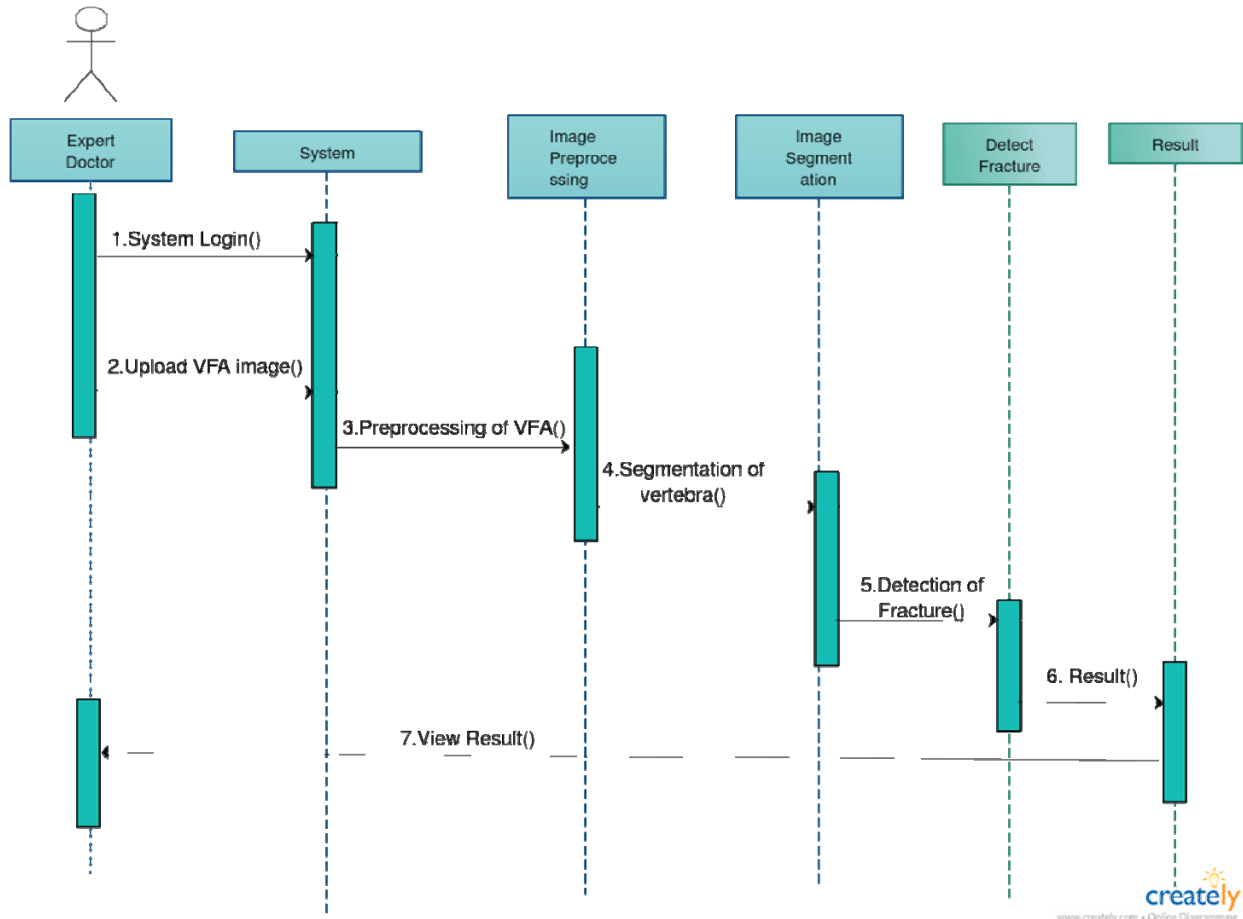


Figure 4.3 Sequence Diagram

4.4 Deployment Diagram

Deployment diagram shows how system will work when it is deployed in its domain and the interaction of components in the system.

The following system deployment diagram shows how the system will work when it is deployed in its domain and the interaction of components in the system.

In this system we are using C# and Open CV library and are deployed on desktop system.

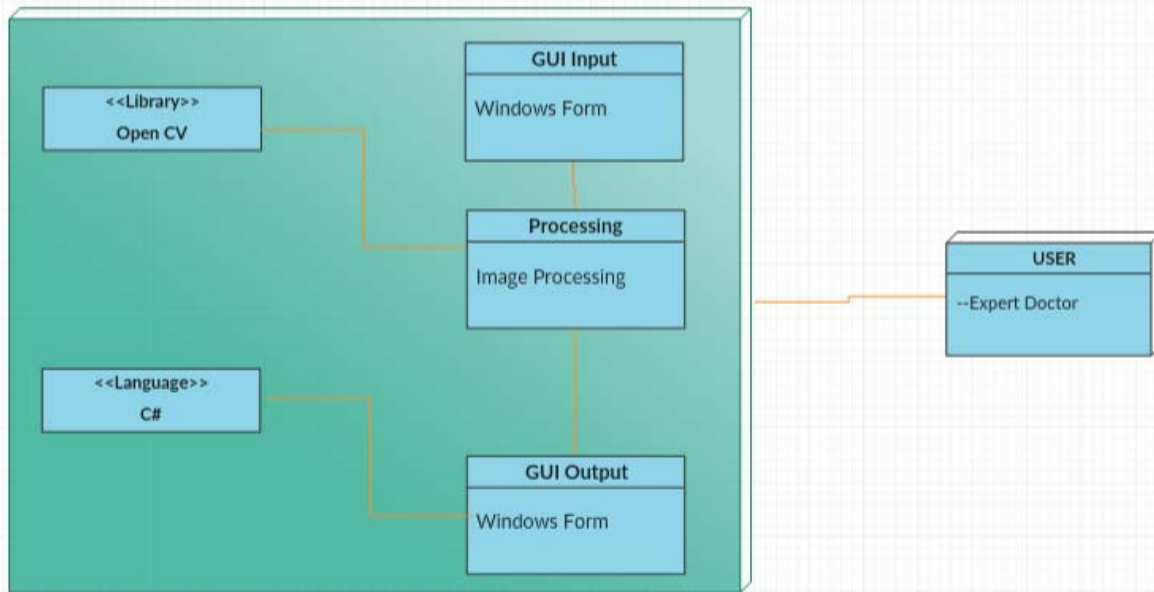


Figure 4.4 Deployment Diagram

4.5 Data flow Diagram

Data flow diagram (DFD) interpret how data is processed by a framework in terms of inputs and outputs.

VFA image will be input of system which can be preprocessed to enhance features if required before analyze then each vertebra of lumbar spine will be segmented and fracture type of each segmented vertebra will be detected

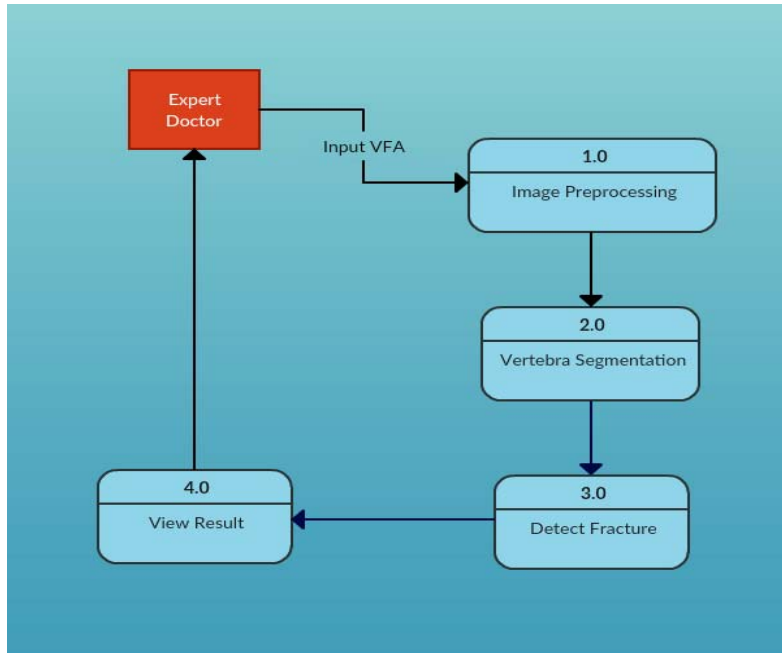


Figure 4.5 Data flow Diagram

4.6 Package Diagram

Package diagram is UML structure diagram which shows structure of the designed system at the level of packages. Each process in system is referred as a separate package. This system has three major packages: image preprocessing, image segmentation and detection of fracture

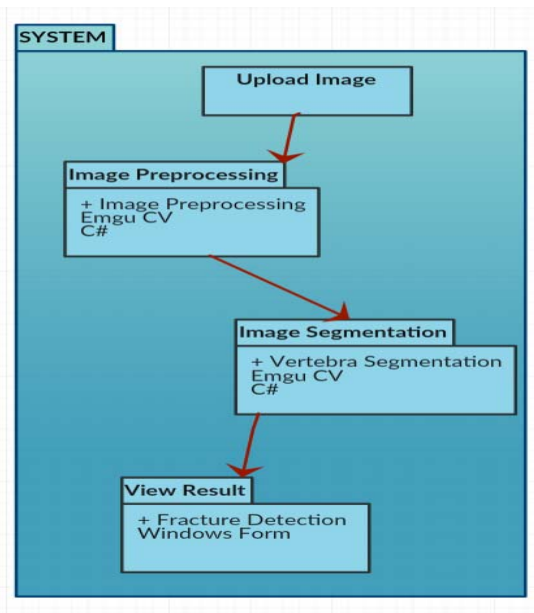


Figure 4.6 Package Diagram

Chapter 5

System Implementation

This chapter will provide a complete overview of algorithms, tools, technologies, libraries and development techniques used to develop this application.

5.1 Tool and technologies

Following are the tool and technologies which I have used for the development of the application.

5.1.1 Visual Studio 2013

Microsoft Visual Studio is an incorporated improvement environment (IDE) from Microsoft. It is utilized to create PC programs for Microsoft Windows, and additionally sites, web applications and web administrations. Visual Studio utilizes Microsoft programming improvement stages, for example, Windows Programming interface, Windows Frames, Windows Presentation Establishment, Windows Store and Microsoft Silverlight. It can create both local code and oversaw code.

Visual Studio underpins distinctive programming. Worked in languages incorporate C, C++ and C++/CLI (by means of Visual C++), VB.NET (by means of Visual Essential .NET), C# (by means of Visual C#), and F# Support for different languages, for example, Python, Ruby, Node.js, and M among others is accessible by means of dialect administrations introduced independently. It additionally supports XML/XSLT, HTML/XHTML, JavaScript and CSS. Java (and J#) were bolstered before.

5.1.2 Emgu CV

Emgu CV is a cross platform .Net wrapper to the OpenCV image processing library, which can easily configure with the visual studio. Emgu CV is written entirely in C#. Allowing OpenCV functions to be called from .NET compatible languages such as C#, VB, VC++, IronPython etc. The wrapper can be compiled by Visual Studio, Xamarin Studio and Unity, it can run on Windows, Linux, Mac OS X, iOS, Android and Windows Phone.

5.2 Languages

The language that has been used for the development of this application is C#. C# is a significant language to use for image processing because it's so powerful. With these image processors, you can change and manipulate colors, image orientations, add filter and blend effects, change image size, and much more by using OpenCV image processing library.

5.3 Dataset

Dataset images are from SpineWeb which is an online collaborative platform open to everyone for who are interested in research. Automatic vertebral fracture analysis and identification from VFA by DXA as training set. It includes antero-posterior and lateral of VFA images but they released some images for training and then they didn't respond for releasing rest of the dataset

so to increase diversity of project I took some images from Islamabad Diagnostic Center (IDC), these images are of lumbar spine.



(a) IDC

(b) Spineweb

Figure 5.1: Dataset Images

	Spineweb	IDC
Training Images	20	5
Test Images	17	3

Table 5.1: Dataset Images for Training and Testing

5.4 Methodology

In this section the methodology and algorithms are going to be discussed which are used in the development of this application.

The following diagram shows the complete process of achieving the final result

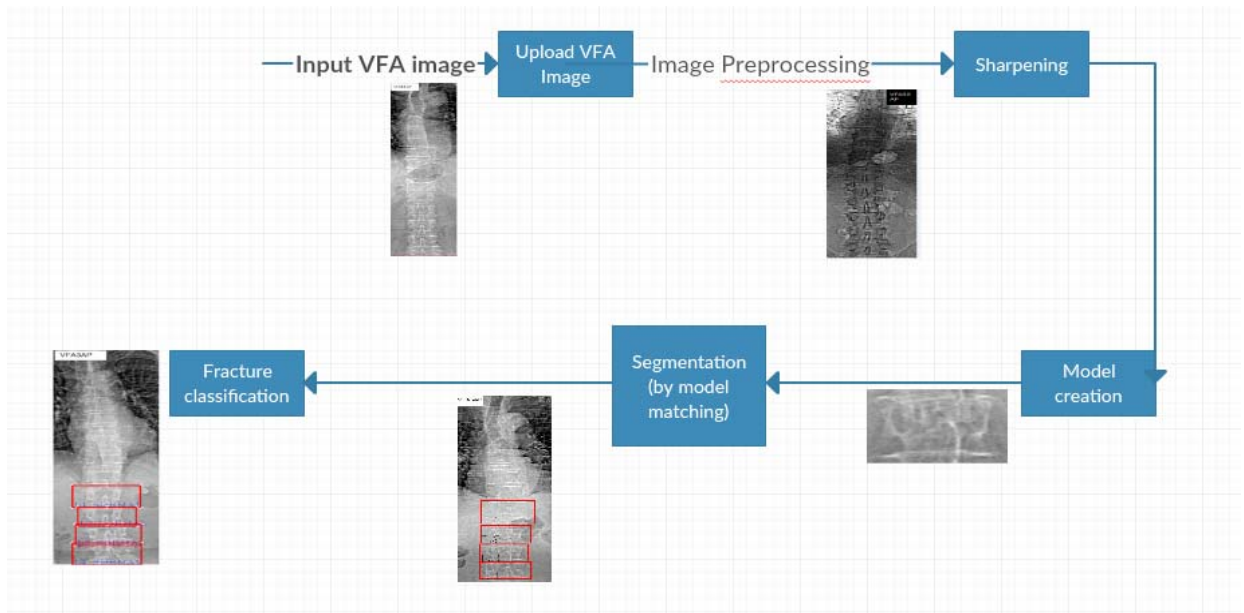
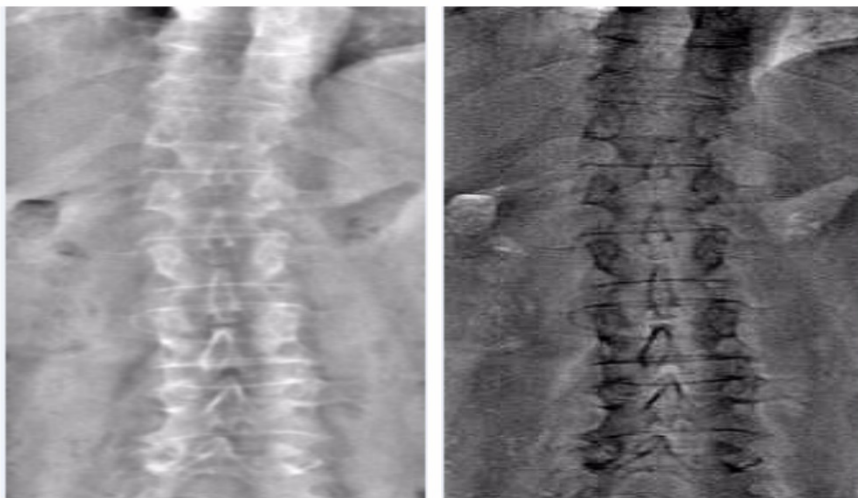


Figure 5.2: Block diagram

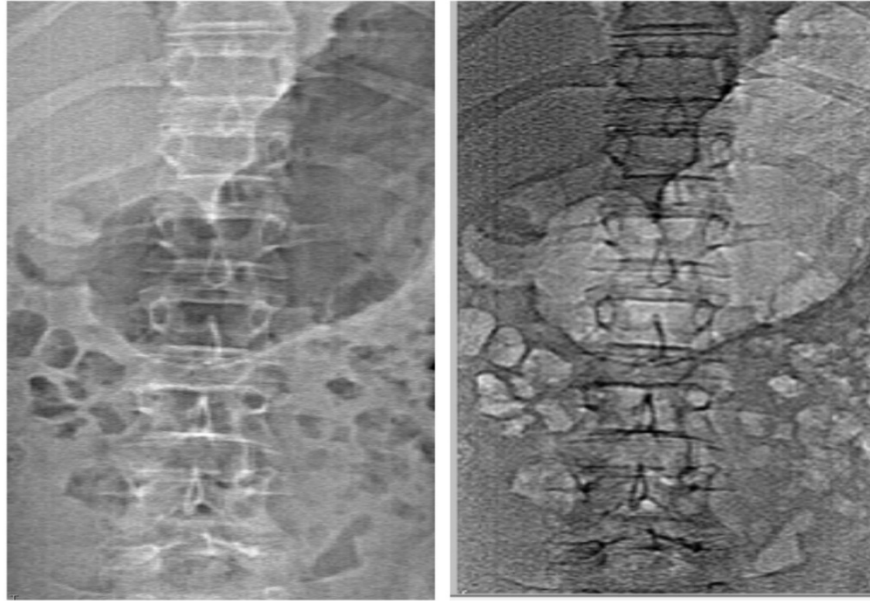
5.3.1 Image Sharpening

Vertebral images by Dual-Energy X-Ray Absorptiometry (DXA) are mostly not clear so to enhance image features some scans require sharpening. So input image can be sharpened by setting a threshold.



(a)

(b)



(a)

(b)

(a)Input image (b) After sharpening filter

Figure 5.2: Image sharpening results

5.3.2 Segmentation

To detect fracture segment each vertebra of lumbar spine for which SURF algorithm is used in which first model is created and then matched it with source image.

5.3.2.1 Model creation

Part of image to be extracted from source image is manually segmented and created as model image[7,8]. Each vertebra is stored as model



Figure 5.3: (a) Training image

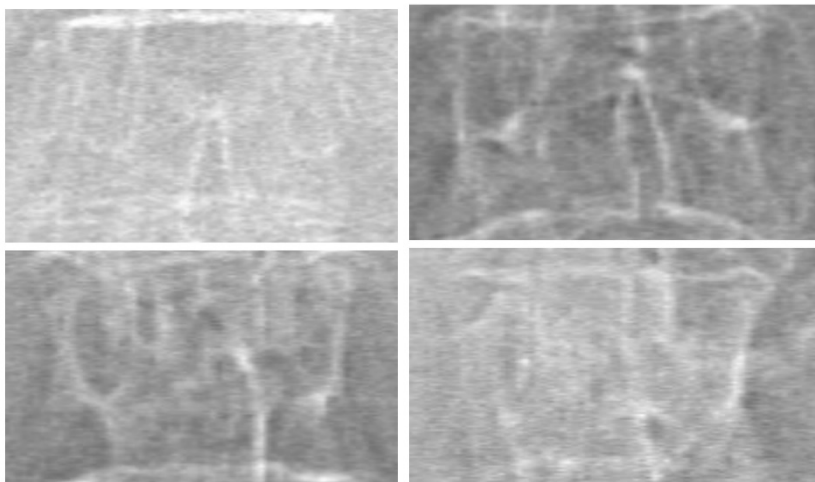


Figure 5.3: (b) An example of L1-L2-L3-L4 (lumbar spine) vertebrae of a patient. Models created from training images

5.3.2.2 Matching

The technique which I have used for the object recognition is called template matching. This technique has two components, such as Source image and Template image. Source image is the image in which we want to find the desired object match. Template image is the image of the object which we have extracted, and will search in the source image to find the match.

Image is recognized by getting the key points from the source image and match them with template images using key points. The system will create a bounding box around each vertebra and will label it with vertebra name (L1-L4).



Figure 5.4: Segmentation of vertebrae.

5.3.3 SURF Algorithm

In computer vision, speeded up robust features (SURF) is a patented local feature detector and descriptor, which was first presented by Herbert Bay, et al., at the 2006 European Conference on Computer Vision. It can be used for tasks such as object recognition, image registration, classification or 3D reconstruction. It is partly inspired by the scale-invariant feature transform (SIFT) descriptor but is several times faster than SIFT. To detect interest points, SURF uses an integer approximation of the determinant of Hessian blob detector, which can be computed with 3 integer operations using a precomputed integral image. Its feature descriptor is based on the sum of the Haar wavelet response around the point of interest. These can also be computed with the aid of the integral image. [9]

In simple words key points are extracted from template image and extracted then source image is compared with images of objects in system by finding features that match based on sum of the Haar wavelet response. So first find the key points of the image region to be extracted, and match it with key points of source image. Each key points has attributes like x axis coordinates and y axis coordinates. If more than 60% key points match in source and template images than it identifies the object otherwise no match. So if the correct match is found then the system will create a bounding box around each vertebra and will label it with vertebra name (L1-L2).

5.3.4 Fracture classification

After segmentation of each vertebra will be classified into respective fracture type i.e. concave, wedge and

crush.

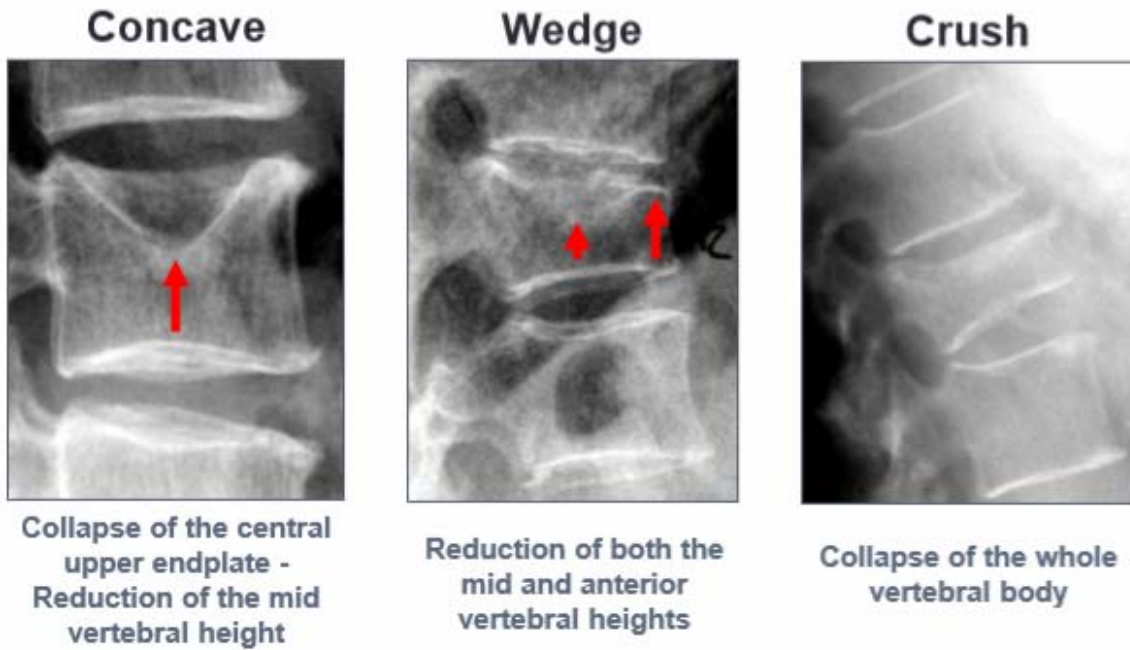


Figure 5.4: An example of type of fractured vertebrae of a patient.

Fractured of each type is classified by rule based classification.



Figure 5.5: Fracture type detected by system of each vertebra.

This chapter presented in detail the system implementation along with the algorithmic details of the system including preprocessing, segmentation and classification. The evaluations carried out to validate the proposed system are presented in the next chapter.

Chapter 6

System Testing and Evaluation

In this chapter we are going to do software testing technique to evaluate the final results of the system that will tell the accuracy and constraints.

6.1 Software Testing Technique

Software testing is the process of validating a system against requirements and evaluating whether the system is performing the tasks it is intended to do.

In programming testing there are diverse structures utilized and there are numerous kind of testing to finish distinctive periods of the testing. The following are some of the software testing techniques which have been used to test application.

- Function Testing

- Performance Testing
- Acceptance Testing

6.1.1 Function Testing

In this testing instead of testing the whole system, main focus is to test the components of the system and their interaction with each other. It has following types.

Unit Testing

Testing the programs units individually if they are working properly. All resources and functions have been tested and are working fine. This project as three major units: image preprocessing, segmentation and classification of fracture.

Integrating Testing

Testing the programs, files and different processes to verify if they have been integrated with each other properly. The integration of all three major units (image preprocessing, segmentation and classification of fracture) have been tested and has produced fair results.

System Testing

Includes wide spectrum of testing such as functionality, and load. The system appears to fulfill all the required nonfunctional requirements.

White Box Testing

Testing the system with knowledge of systems internal structure, lines of code and methodologies. System produced fair results.

Black Box Testing

Examines the program that is accessible from outside. Applies the input to a program and observe the externally visible outcome. Uploaded VFA image by user is processed accurately according to users demand and produced fair results.

6.1.2 Performance Testing

Software performance testing can be defined as process of testing the performance of system. This process involves that how reliable, accurate and effective the system is. In other words in this we check all aspects regarding to the performance of system. Testing the security requirements of the system. The system does not have any strict security measures because it does not have any confidential information about users.

6.3 Test Cases

Test Case # 1: Installing Application

The application is to be installed on windows. To run the application the device should have openCV 2.4 installed on device. If not installed the application will ask the user to install the openCV.

Test Case # 2: User Login

Test Case Id	02
Description	Tests the sign in screen

Application for	Window desktop systems
Requirements	Application is to be installed on windows with required condition
Steps to be Taken	<ol style="list-style-type: none"> 1. Open the home screen 2. Enter username and password 4. Verify that username and password entered is correct. 5. user is entered into system
Expected Result	user is login into system
Actual Result	login successful
Status	Success
Remarks	N/A

Table 6.1: Test Case 2

Test Case # 3: Load Image

Test Case Id	03
Description	Test that the image uploaded successfully or not?
Application for	Window desktop systems
Requirements	User should be logged in
Steps to be Taken	<ol style="list-style-type: none"> 1. Click button to open file dialogue box. 2. Select image from the dialogue box. 3. Image should be display in picture box.
Expected Result	Image should be displayed in picture box.
Actual Result	Image is displayed in picture box.
Status	Success
Remarks	N/A

Table 6.2: Test Case 3

Test Case # 4: Analyze Image button

Test Case Id	04
Description	Tests to check if the image is processing
Application for	Window desktop systems
Requirements	Image should be uploaded from system and displayed in picture box
Steps to be Taken	<ol style="list-style-type: none"> 1. Click on the analyze image button so the uploaded image could be processed 2. Verify that process image button is working properly 3. Verify that the images are processed correctly according to

	the requirements
Expected Result	system should start processing image
Actual Result	system started processing image
Status	Success
Remarks	N/A

Table 6.3: Test Case 4

Test Case # 5: Segment vertebra

Test Case Id	05
Description	Tests to check if each vertebra of lumbar spine is segmented correctly
Application for	Window desktop systems
Requirements	User should Click on the analyze image button so the uploaded image could be processed
Steps to be Taken	<ol style="list-style-type: none"> 1. Click on the analyze image button so the uploaded image could be processed 2. Verify that all four vertebrae are segmented correctly and are labeled
Expected Result	System should segment and label vertebrae correctly.
Actual Result	System segmented correctly and labeled vertebrae correctly.
Status	Success
Remarks	N/A

Table 6.4: Test Case 5

Test Case # 6: Fracture Type Image button

Test Case Id	06
Description	Tests to check if the Fracture Type Image button working properly.
Application for	Window desktop systems
Requirements	All four vertebrae are segmented correctly and are labeled.

Steps to be Taken	<ol style="list-style-type: none"> 1. Click on the Fracture Type Image button so the segmented image could be processed 2. Verify that process image button is working properly 3. Verify that the images are processed correctly according to the requirements
Expected Result	system should start processing image
Actual Result	system started processing image
Status	Success
Remarks	N/A

Table 6.5: Test Case 6

Test Case # 7: Classification of Fracture

Test Case Id	07
Description	Tests to check if the Fracture type is correctly classified.
Application for	Window desktop systems
Requirements	User should Click on the Fracture type button so the segmented image could be processed
Steps to be Taken	<ol style="list-style-type: none"> 1. Click on the Fracture Type Image button so the segmented image could be processed 2. Verify that processed image correctly displayed fracture type
Expected Result	system should display fracture type
Actual Result	system displayed fracture type
Status	Success
Remarks	N/A

Table 6.6: Test Case 7

Test Case # 8: Save Image

Test Case Id	08
Description	Tests to check if the user want to save result image in the system
Application for	Window desktop systems
Requirements	User should Click on the SaveImage button so the result image is saved

Steps to be Taken	<ol style="list-style-type: none"> 1. Click on the SaveImage button so result image is saved 2. Verify that image is saved in the system.
Expected Result	System should save result image in the system.
Actual Result	System saved result image in the system.
Status	Success
Remarks	N/A

Table 6.7: Test Case 8

Test Case # 9: Load Image Randomly

Test Case Id	09
Description	Test that uploaded image with the different attributes work perfectly?
Application for	Window desktop systems
Requirements	User should be logged in
Steps to be Taken	<ol style="list-style-type: none"> 1. Upload Image from system 2. Blur, negative, binary image give required results.
Expected Result	System should analyze image
Actual Result	System didn't analyzed image properly
Status	Fail
Remarks	N/A

Table 6.8: Test Case 9

Test Case # 10: Logout

Test Case Id	10
Description	Test that uploaded image with the different attributes work perfectly?
Application for	Window desktop systems
Requirements	User should be logged in
Steps to be Taken	<ol style="list-style-type: none"> 1. user press Logout button

Expected Result	User should logout from his/her account.
Actual Result	User logout successfully.
Status	Pass
Remarks	N/A

Table 6.9: Test Case 10

6.4 Results and Evaluation

Accuracy graph is a visualization that displays the number and percentage of images that are correctly detected and the total accuracy of the application is 75%. Factors such as poor image quality, lack of test images affected the accuracy of the application.

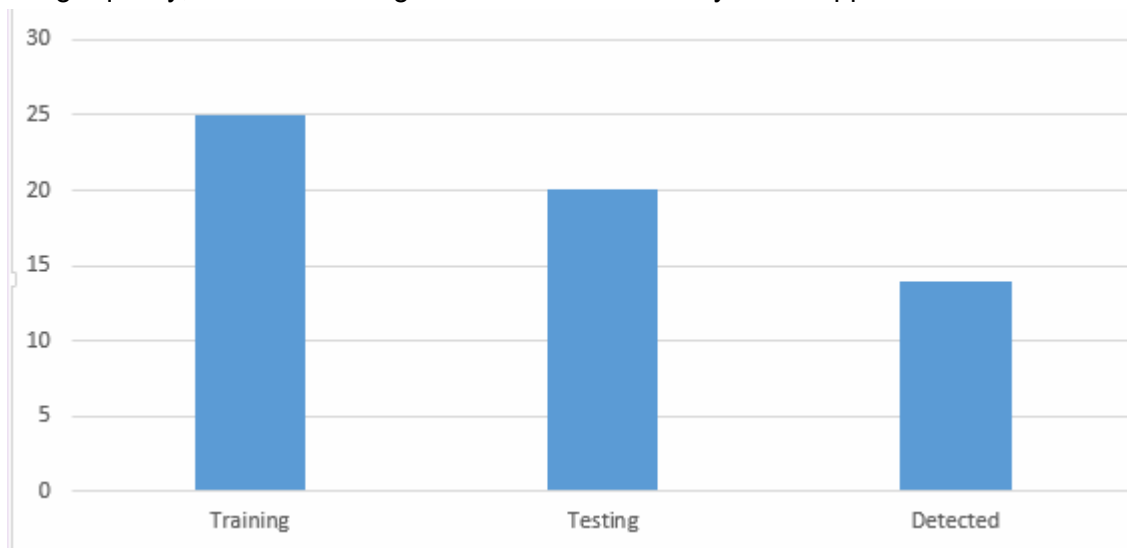


Figure 6.1: Accuracy Graph

Chapter 7

Conclusion

7.1 Conclusion

This project was aimed to develop a Window desktop application that would take VFA images as input, process that image by using different techniques of image processing to detect vertebral fracture. Input image is preprocessed if required to sharpen features of image then

segment lumbar spine vertebrae (L1-L4). Segmented vertebrae are then classified into three fracture types, i.e.: wedge, concave and crush.

This project presented a challenge of learning a new technology, a new tool and a new language for me. More, I have learnt short term project planning and implementation which includes:

- Gathering requirements
- Research about the domain
- System design
- Implementation and basic
- Functional and quality testing.
- GUI design
- Interaction with different tools and technologies.
- Time management.

7.2 Future work

The future versions of this system can be refined by a robust training and testing images which have better features so processing can be easy on it and the accuracy can be improved.

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