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Augmented Forearm Fracture Surgery

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Abstract

The main aim of this project is to focus on providing an interactive tool which will help the user in preoperative planning of the forearm surgery. The key concept of our approach is to directly simulate the forearm motion instead of a physically based model and then perform the required forearm fracture surgery. To be able to visualize of data overlaying the part which the clinician is viewing offers interesting possibilities.

Conducting tests on a physical system would be impossible: for example, because of the high price, or because of the duration of the test in actual time is impractical. To avoid all such circumstances, we will introduce a tool that will give an augmented view of a forearm and will let you do all the learning of treating a fracture of the forearm.

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Acronyms and Abbreviation

2D	Two Dimensional
3D	Three Dimensional
SRS	Software Requirements Specification
SDK	Software Development Kit
AR	Augmented Reality
UML	Unified Modeling Language
App	Application
GUI	Graphical User Interface
UV	Ultraviolet

Chapter 1

Introduction

1.1. Overview

Emergence of computer technology has given birth to a many different dimension. One of the emerged dimensions in computer technology is augmented reality, where a computer-generated object is placed onto the user's vision of the real world. Augmented simulations will prove as training aid for surgeons and medical students in preoperative planning of osteotomy and for medical visualization tasks [1]. Previously 2D pictures, artificial structures [2] and artificial bodies [3] were used for learning purposes, but these methods are not interactive.

1.1.1. Augmented Reality

Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented by computer-generated sensory input as sound, image or video. It is related to a more general concept called mediated reality, in which a view of reality is modified by a computer. As a result, the technology functions by enhancing one's current perception of reality [4].

Augmented reality brings out the components of the digital world into a person's perceived real world. One example is an AR helmet for construction workers which displays information about the construction sites. The first functional AR system that provided immersive mixed reality experiences for users were invented in the early 1990's, starting with the Virtual Fixtures system developed at the U.S. Air Force's Armstrong Labs in 1992 [5].

Augmented reality apps are written in special 3D programs that allow the developer to tie animation or contextual digital information in the computer program to an augmented reality marker in the real world. When a computing device's AR app or browser plug-in receives digital information from a known marker, it begins to execute the marker's code and layer the correct image or images [6].

The project focuses on providing an interactive tool which will help the user in preoperative planning of the forearm surgery. The key concept of this work is to directly simulate the forearm motion instead of a physically based model and then perform the required forearm fracture surgery. To be able to visualize data overlaying the part which the clinician is viewing offers interesting possibilities.

While being able to manipulate all this virtually, would make it more intuitive not otherwise possible [1].

1.2. Objective

To provide an augmented view of a forearm to work on and to perform preoperative/operative surgeries on it rather than performing it directly on human forearm to avoid any risks and complications.

1.3. Problem Description

Conducting tests on a physical system would be impossible: for example, because of the high price or because of the duration of the test in real time is impractical. To avoid all such circumstances, we introduce a tool that gives an augmented view of a forearm and let you do the fracture treatment of the forearm.

1.4. Project Scope

We develop an interactive mobile simulator that guides the user step-by-step through every part of the fracture surgery. The application helps in:

- ✓ Practice the fracture surgery anytime [7]
- ✓ Learn how to operate fracture surgery
- ✓ Experience realistic surgical environments created with augmented reality

First the App detects the forearm using the markers that are set and as per these markers the model is augmented. App provides a user-friendly interface that will allow user to choose the plates for placement on the bones to drill them. Several plates are available to choose from different sizes and shapes. The operating tools or models used in the application are mostly dynamic. Doctors, medical students, anatomy class, even patients will find this surgery training application useful [8] because this application helps them to understand how the fracture surgery take place in real environment and they also use it for learning purpose.

1.5. Tools/Technology

A tool or software development tool is a computer program that use to create, debug, maintain, or support other programs and applications. The most basic tools are a source code editor and a compiler or interpreter, which are used generally and continuously [9]. The tools that are used to make this application are:

- ✓ Unity3D
- ✓ MonoDevelop
- ✓ Blender
- ✓ Vuforia
- ✓ EDraw Max

1.6. Outline

This report is organized in the following chapter 2.

Chapter 2

Literature Review

2.1. Medical Applications

Mobile phones are turn out to be main part of our society, every person from primary school kids to senior citizens owing at least one or two. Although these applications have made our lives easier. The applications related to medical field used by health care professionals has transformed many aspects of clinical practice. These mobile devices have become common place in health care settings, leading to rapid growth in the development of medical software applications for these platforms [10].

Several applications are now available to help health care professionals with various important tasks, such as: information and time management [11]; health record maintenance [12]; communications and consulting [13]; information gathering; patient management and monitoring [14]; and medical education and training [15].

The application proposed is based on augmented reality. This application is for Android platform and uses the mobile camera to perform the surgery. The application will detect a real arm and a 3D model of arm is augmented on it. After augmentation, user will perform an appropriate forearm fracture surgery on that model.

Many applications already exist on the forearm fracture surgery, “Arm Surgery Bone Doctor” made by the oxoapps.com is one of them but all these applications are not related to augmented reality which means having no connection with the reality.

The existed application is made in a virtual surgery room. This application takes some time to go to the surgery. It checks the temperature of patient’s body, blood pressure, apply oxygen mask, injecting medicine through injections and then it goes for the surgery. This is very time consuming process. There is no need of such things to do for learning the steps of fracture surgery. These things are required but they are not the part of the surgery.

2.2. Augmented Forearm Fracture Surgery

The proposed system eliminates the virtual environment and make it a realistic one, which is based on augmented reality. This makes the application more useful to the end users. The application do not have extra or irrelevant steps which is the greatest advantage over the previous existing applications.

The environment of proposed application is real but the fracture surgery is performed on a 3D arm model which is augmented on the human arm by scanning the target and the equipment used in the surgery are mostly 3D models. Once the arm model is augmented, user performs the fracture surgery on that model in the real environment.

Chapter 3

Requirement Specification

A software requirements specification (SRS) is a description of a software system to be developed. It lays out functional and non-functional requirements, and may include a set of use cases that describe user interactions that the software must provide. The software requirements specification document enlists enough and necessary requirements that are required for the project development [16].

3.1. Augmented Surgery Application

The proposed system is based on augmented reality and the final product is an android application. The sets involved in the surgery application is as follows:

3.1.1. Arm model augmentation

The environment of the system is real but the fracture surgery is performed on a 3D arm model which is augmented on the arm by scanning the target.

3.1.2. Target Scanning

Place the phone camera on the arm so the application will detect the human arm and augment 3D arm model on it.

3.1.3. Mark Skin

User first mark the arm skin with a marker to set the position for cut.

3.1.4. Apply Payodeen/Spirit

Payodeen/Spirit will be applied on the arm to clean it.

3.1.5. Cut the Skin

Cut the skin with the cutter where the area is marked.

3.1.6. Open the Cut

With the help of dilator cut will be opened to go to the fractured bone.

3.1.7. Straight the Bone

When the fractured bone is visible, user should move the bone to its original location with the help of dilator.

3.1.8. Apply Plate

Plate is placed on the bone after moving it to its original location.

3.1.9. Screw the Plate

Screws are placed on the plate and are drilled with the help of a drill or a screwing tool.

3.1.10. Close the Cut

Wound/Cut will be closed after applying the plates. To do so, dilator will be removed.

3.1.11. Stitch the Cut

Stitched the wound/cut with needle to close it properly.

3.1.12. Plaster the Arm

Apply plaster on the arm to make it straight so the bone will not move.

3.2. Requirement Specifications

3.2.1. Functional Requirements

- The application must be designed to offer a live event operation on an augmented arm.
- The application only deals in operating the forearm bone.
- The application lets user to execute the normal operation routine.

3.2.2. Non-Functional Requirements

- **Camera Quality**
Camera quality must be good enough so that it can scan the target properly.
- **Light**
The light must not be too bright or too dim.
- **Performance Requirements**
The loading time of graphical user interface screens shall take no longer than one seconds.
- **Design Constraints**
This application will be a standalone application.

- **Standards Compliance**
There will be consistency in variable names within the system. The graphical user interface will have a consistent look and feel.
- **Availability**
The system will be accessible anywhere anytime.
- **Maintainability**
The system will have user friendly interfaces which will make it easy to use and maintain.
- **Portability**
The application will be portable easily as it will be accessible on any mobile phone or tablets having a camera.

3.3. Use case Design

Use case

Use case is a list of actions or event steps, typically defining the interactions between a role and a system, to achieve a goal [17]. The actor can be a human or other external system.

Actor: User

This system has three type of users i.e. (1) Students, (2) Teachers and (3) Doctors. All the functions are performed by a single user at a time.

User will scan an image target, i.e. an arm, a 3D model is augmented on it. After augmentation, user will mark the skin with a marker. Spirit/Payodeen is applied on the skin after marking. With the help of a blade, user will cut the skin of arm and with the use of dilator, cut will be open. Now the fractured bone is visible to the user. User will place a plate on the bone after setting the bone on its original position and screw the plate with the bone with the help of screwing tool. After doing this, remove the dilator to close the cut and stitch it. In the end plaster the arm to make it straighten.

The use cases of this system are as follows:

3.3.1. Scan Target

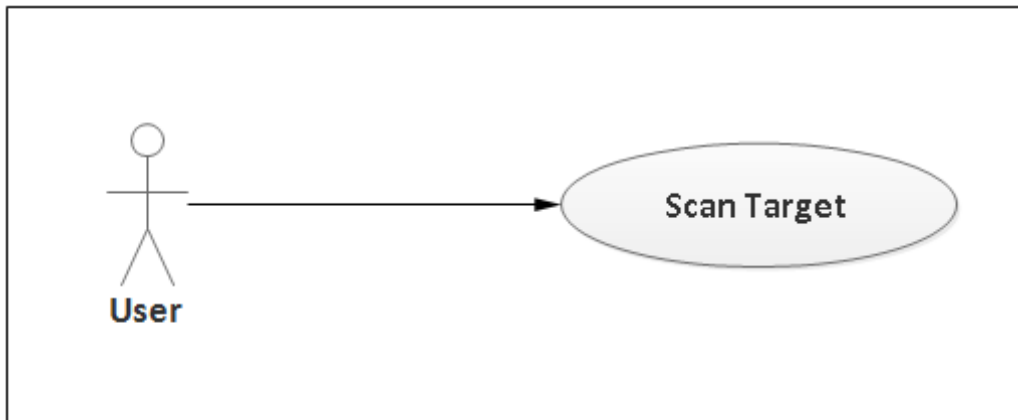


Figure 3.1 Scan target

Table 3.1 Scan Target

Use case name	Scan Target
Brief description	Scanning the target by placing camera on it.
Pre-condition	Application is running.
Steps	<ul style="list-style-type: none">• Start Application• Open Vuforia camera• Place phone exactly on the target• Scan target• Press next button to-go-to next step
Post-condition	Target is scanned and model is augmented on the target.

3.3.2. Mark Skin

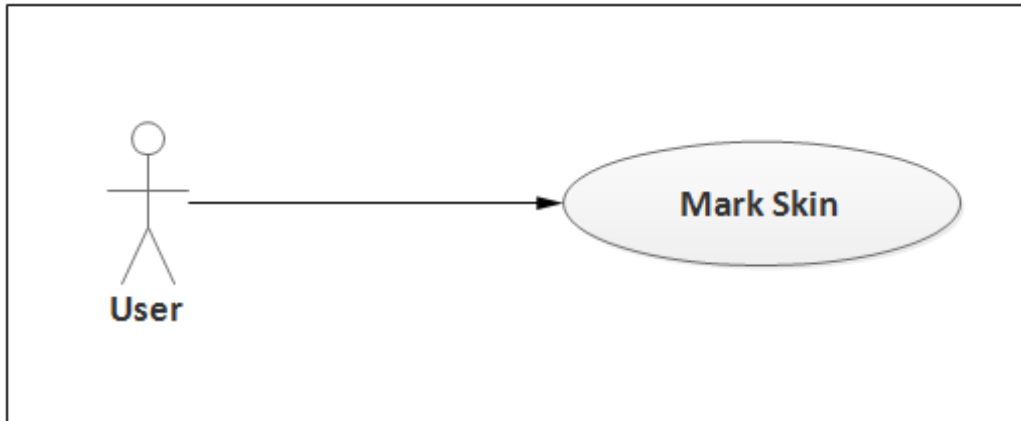


Figure 3.2 Mark skin

Table 3.2 Mark skin

Use case name	Mark Skin
Brief description	Mark the skin with marker to identify from where to cut.
Pre-condition	Application is running and the target is set.
Steps	<ul style="list-style-type: none">• Press play button to start surgery• Drag and drop marker on the arm model• Press next button to-go-to next step
Post-condition	The marker is marked properly.

3.3.3. Apply spirit/payodeen

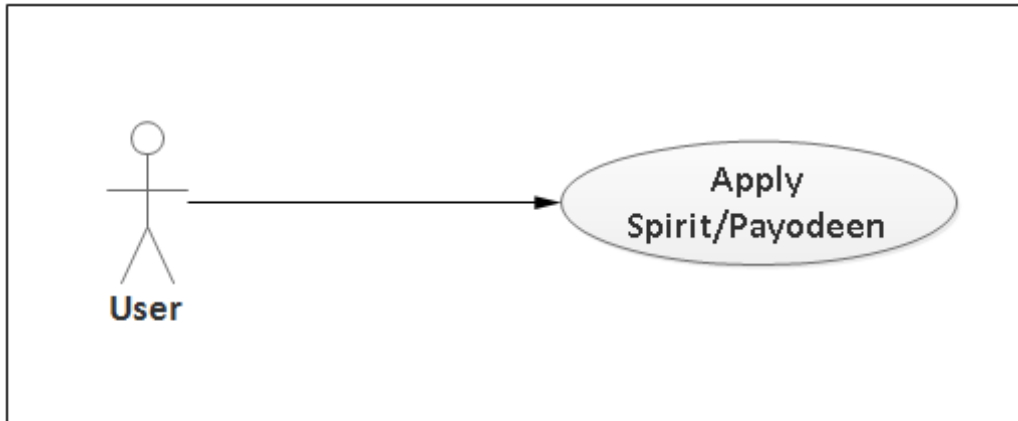


Figure 3.3 Apply spirit/payodeen

Table 3.3 Apply sedatives

Use case name	Apply Spirit/Payodeen
Brief description	Apply sedatives over the augmented arm model.
Pre-condition	Skin is marked properly.
Steps	<ul style="list-style-type: none">• Drag and drop the tool to apply payodeen/spirit• Press next button to-go-to next step
Post-condition	The sedatives is applied properly and on the place required.

3.3.4. Cut Skin

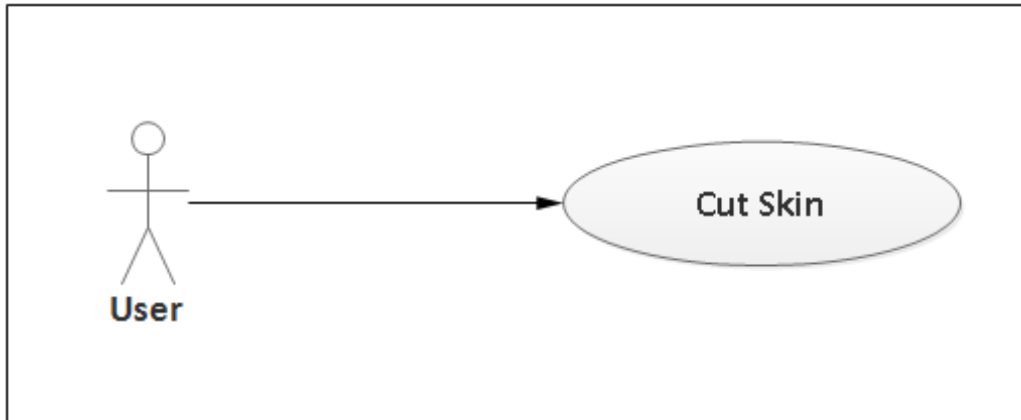


Figure 3.4 Cut skin

Table 3.4 Cut skin with blade

Use case name	Cut skin
Brief description	Cut skin with blade.
Pre-condition	Sedative is applied over the arm skin.
Steps	<ul style="list-style-type: none">• Drag and drop blade to cut skin• Press next button to-go-to next step
Post-condition	Skin cuts in a straight line and over the marked area.

3.3.5. Open the Cut

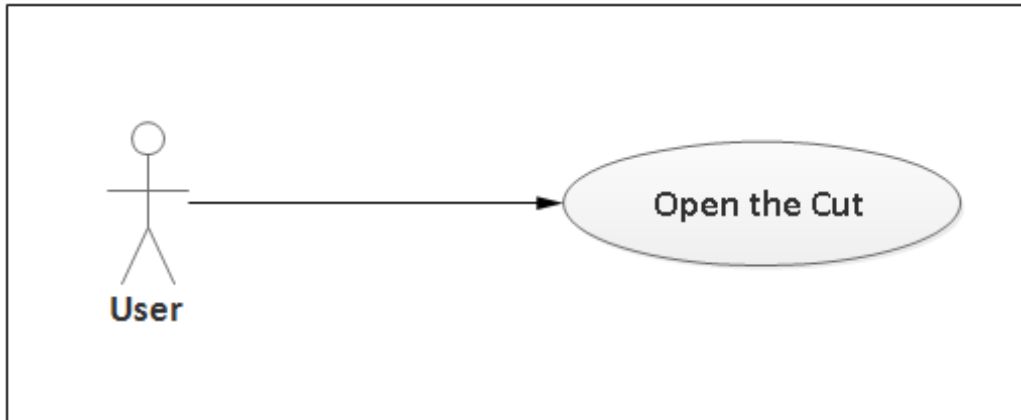


Figure 3.5 Open the cut

Table 3.5 Open skin after successful cutting

Use case name	Open the cut
Brief description	Open the skin after successful cutting with the help of dilator.
Pre-condition	Skin is properly cut.
Steps	<ul style="list-style-type: none">• Drag and drop dilator into the cut to open skin• Press next button to-go-to next step
Post-condition	The cut is opened using the tool (dilator) appropriately.

3.3.6. Straight the Bone

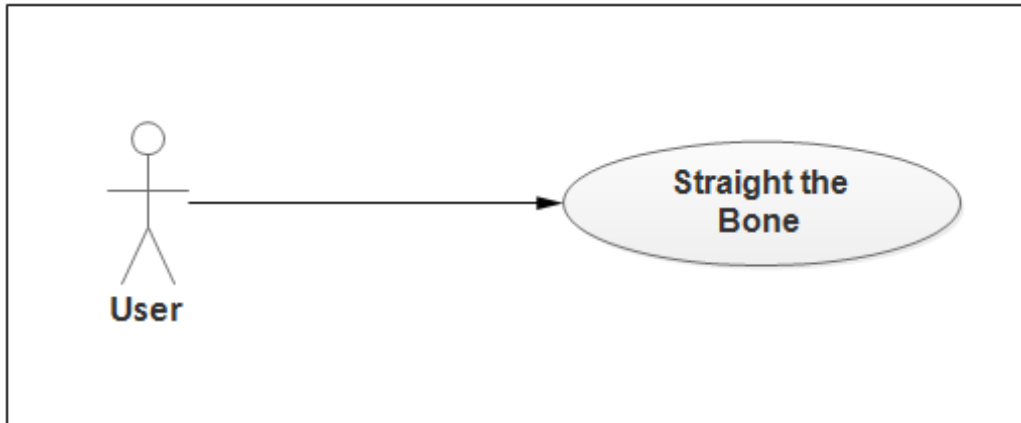


Figure 3.6 Straight the bone

Table 3.6 Align misplaced bone

Use case name	Straight the bone
Brief description	Align the misplaced bone with the help of another dilator.
Pre-condition	Skin was opened.
Steps	<ul style="list-style-type: none">• Drag dilator towards the fractured bone• Straight the bone with dilator• Press next button to-go-to next step
Post-condition	The bone is aligned properly

3.3.7. Apply Plate

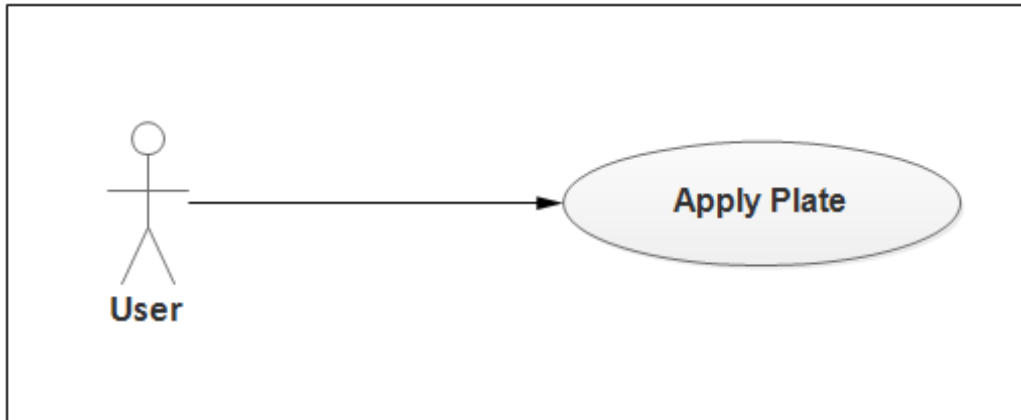


Figure 3.7 Apply plate

Table 3.7 Applying the plate over the cracked/broken bone

Use case name	Apply plate
Brief description	Apply plate over the cracked/broken bone.
Pre-condition	Bone is aligned.
Steps	<ul style="list-style-type: none">• Drag the appropriate plate over the bone• Press next button to-go-to next step
Post-condition	Plate is placed properly over the bone.

3.3.8. Screw

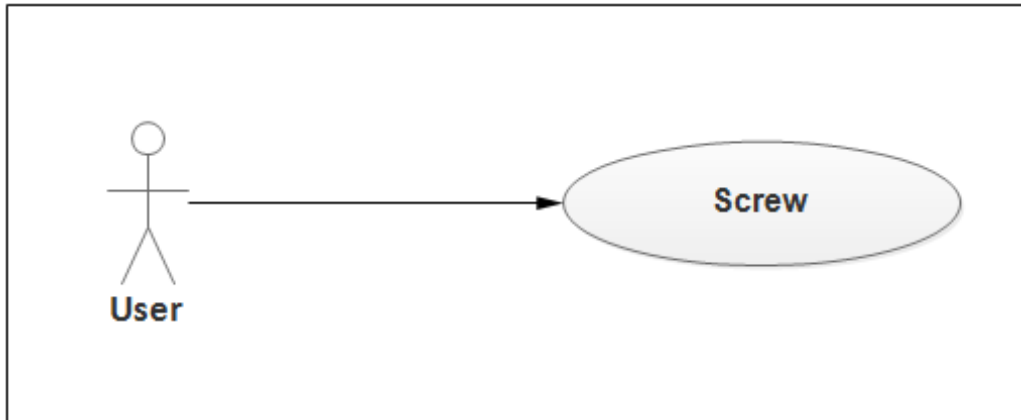


Figure 3.8 Screw

Table 3.8 Screw plate over the bone

Use case name	Screw
Brief description	Screw plate over the bone.
Pre-condition	Plate is placed over the bone.
Steps	<ul style="list-style-type: none">• Drag screwing tool over the screws to close them• Press next button to-go-to next step
Post-condition	The plate is screwed properly using the appropriate tool.

3.3.9. Close the Cut

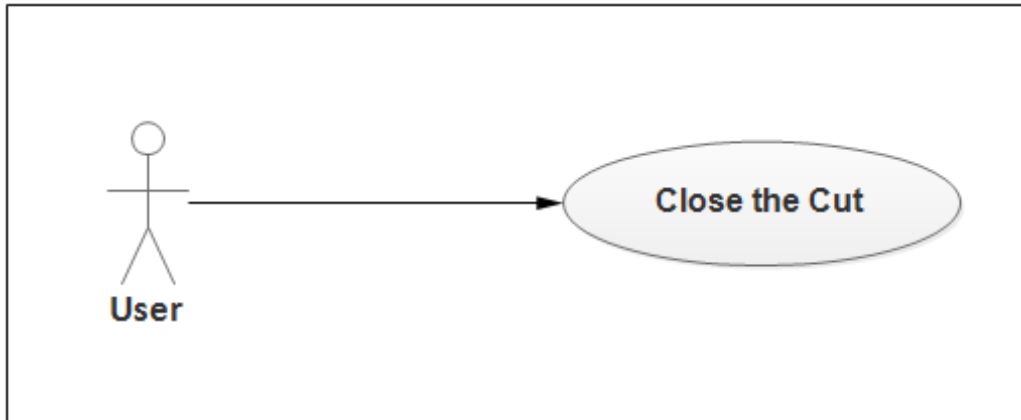


Figure 3.9 Close the cut

Table 3.9 Close the cut that was opened

Use case name	Close the cut
Brief description	Close the cut that was previously opened.
Pre-condition	The plate is screwed properly.
Steps	<ul style="list-style-type: none">• Remove dilator to close the cut• Press next button to-go-to next step
Post-condition	The cut is closed properly.

3.3.10. Stitch the Cut

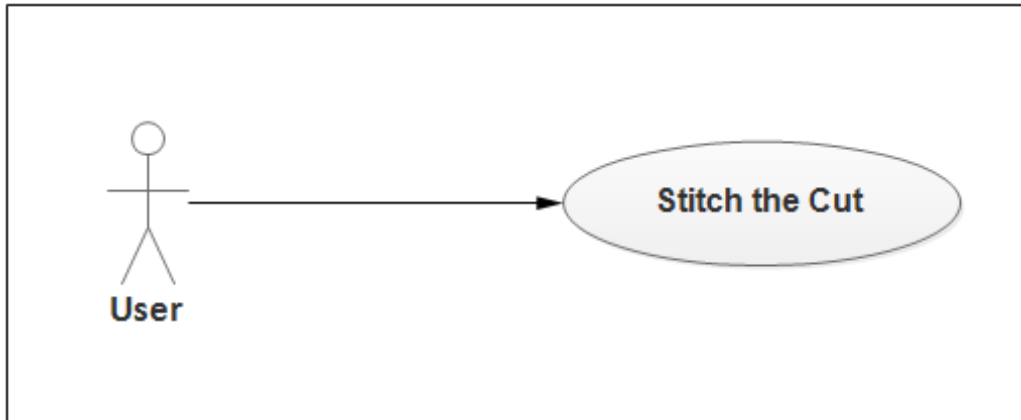


Figure 3.10 Stitch the cut

Table 3.10 Stitch the cut after closing

Use case name	Stitch the cut
Brief description	Stitch the cut to close it properly after successful placement of plate.
Pre-condition	The cut is held close to stitch it back.
Steps	<ul style="list-style-type: none">• Drag the needle over the cut to stitch it• Press next button to-go-to next step
Post-condition	Stitch the cut properly and carefully.

3.3.11. Plaster the Arm

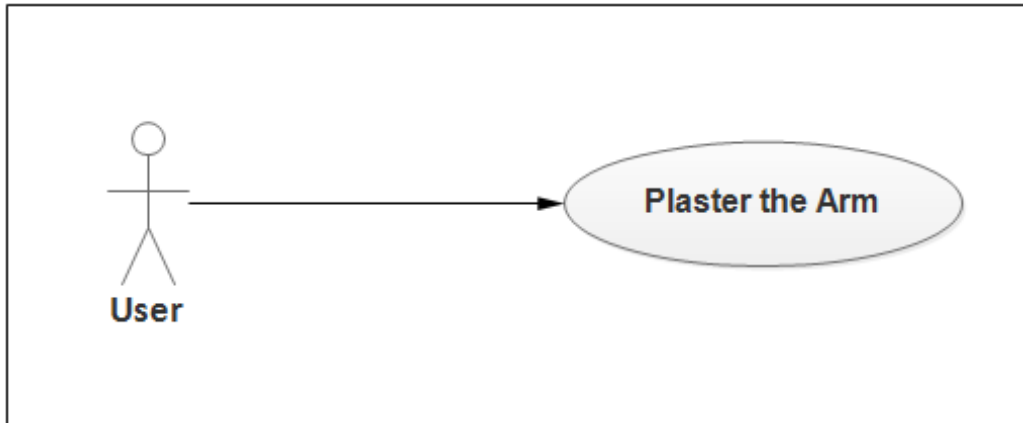


Figure 3.11 Plaster the arm

Table 3.11 Apply plaster on the arm

Use case name	Plaster the arm
Brief description	Apply plaster on the arm after stitching it back.
Pre-condition	The cut is stitched properly.
Steps	<ul style="list-style-type: none">• Plaster is applied• Press replay button to start the surgery again from the main screen
Post-condition	The plaster is applied on the arm for it to dry and be held still for the bone to heal in proper place.

Chapter 4

System Design

System design is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements. Systems design could be seen as the application of systems theory to product development [18].

4.1. System Architecture

System architecture is a conceptual model that defines the structure, behavior, and more views of a system [19]. The following diagram shows the general architecture of our system. It shows how the system will function. System architecture explains the basic idea of the system which recognizes the human arm by scanning the targets and surgery is performed on the augmented model.

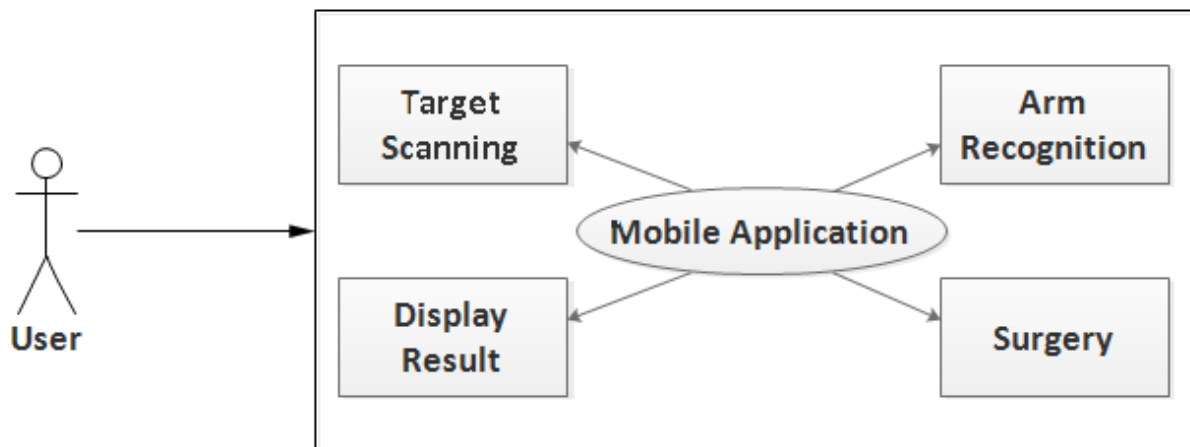


Fig 4.1 System architecture

The application has four modules and they are as follows:

4.1.1. Target Scanning

Target is scanned with the help of mobile camera and it is placed over the target.

4.1.2. Arm Recognition

Target is already saved in the database and the patterns are set. Through these patterns, target is scanned.

4.1.3. Surgery

After successful augmentation of 3D arm model, surgery is performed by the user. Surgery contains the following steps:

- Mark arm
- Apply payodeen/spirit
- Cut the Skin
- Open the cut
- Straight the bone
- Apply plate
- Screw the plate
- Close the cut
- Stitch the cut
- Plaster the arm

4.1.4. Display Result

Result is displayed frequently after every step of the surgery. When the user completed first step of surgery and goes to the second step, there is no going back option available in the application. Users have to be careful to perform the surgery properly. Information of every step is available in the application to ease the user.

4.2. Design Methodology

We use agile model for the implementation of project so that we have room for improvements since with time technology is advancing. When new changes are needed to be implemented! The freedom agile gives to change is very important. New changes can be implemented at very little cost because of the frequency of new increments that are produced. To implement a new feature, the developers need to lose only the work of a few days, or even only hours, to roll back and implement it [20].

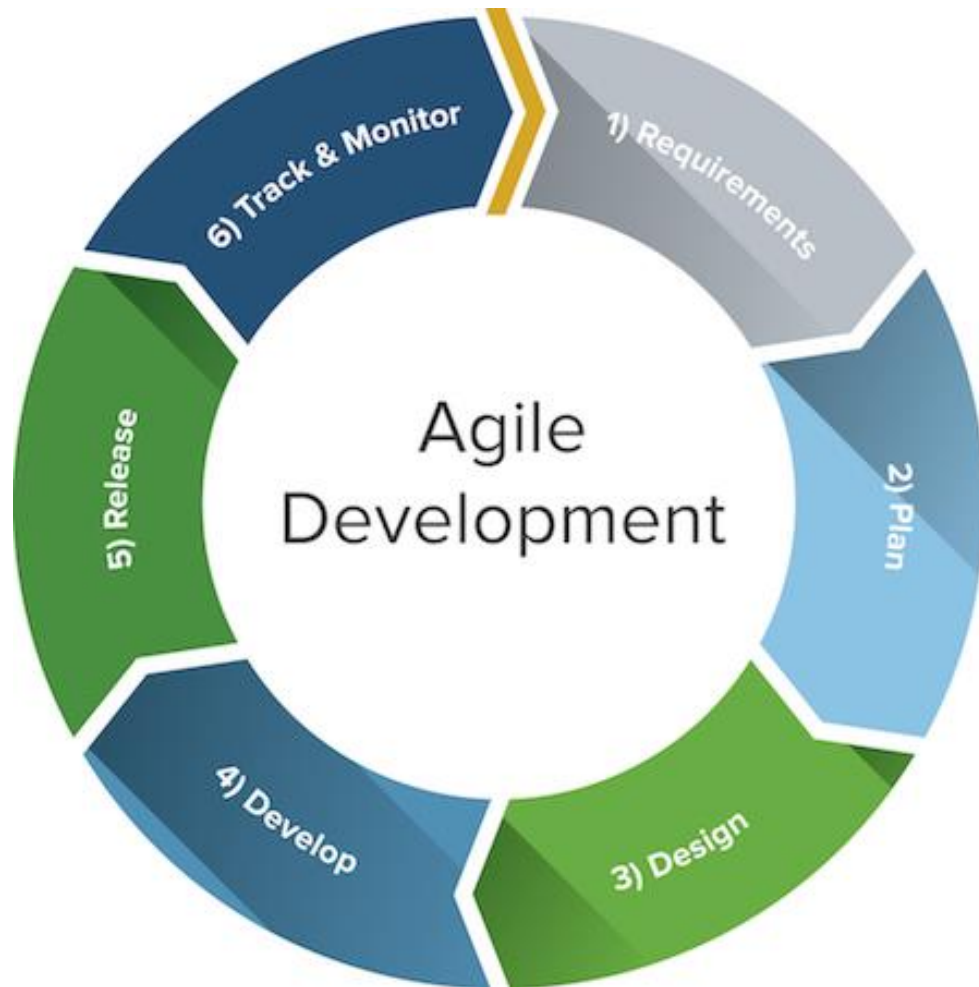


Fig 4.2 Design methodology

4.3. High Level Diagram

4.3.1. Package Diagram

Package diagram is UML structure diagram which shows packages and dependencies between the packages. It is a general purpose mechanism to organize elements into groups to provide better structure for system model [21]. The diagram shows the logical functional elements of the system. Each component represents alike grouping of functionality.

The application have four components i.e. (1) Application: based on augmented reality, (2) Camera: which includes camera quality and focusing image, (3) Target Scanning: includes image target recognition or pattern recognition and after successful recognition model is augmented and (4) Surgery: include all the important steps which are already discussed in the previous chapters.

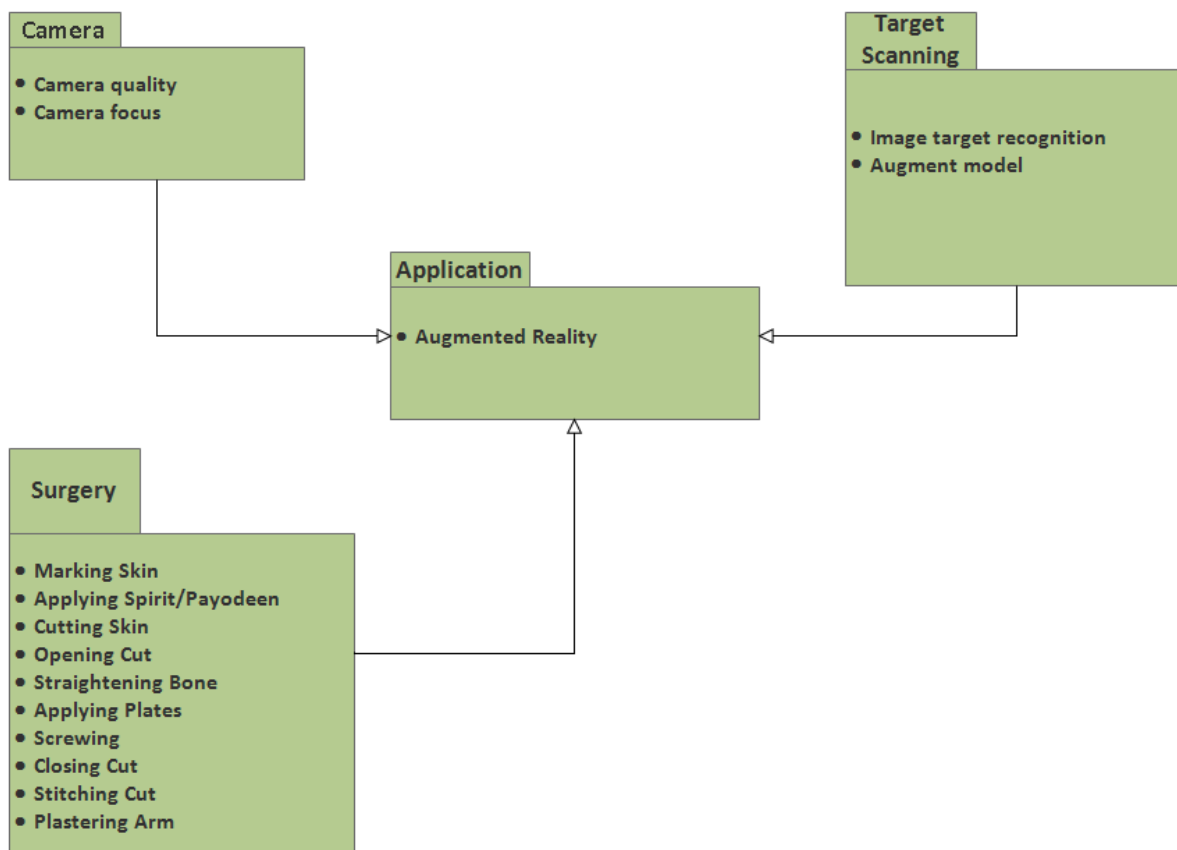


Fig 4.3 Package diagram

4.4. Activity Diagram

Activity diagram is basically a flow chart to represent the flow from one activity to another activity. The activity can be described as an operation of the system. So the control flow is drawn from one operation to another. This flow can be sequential, branched or concurrent [22].

The activity diagram of the application shows the activities of the application in which order it executes.

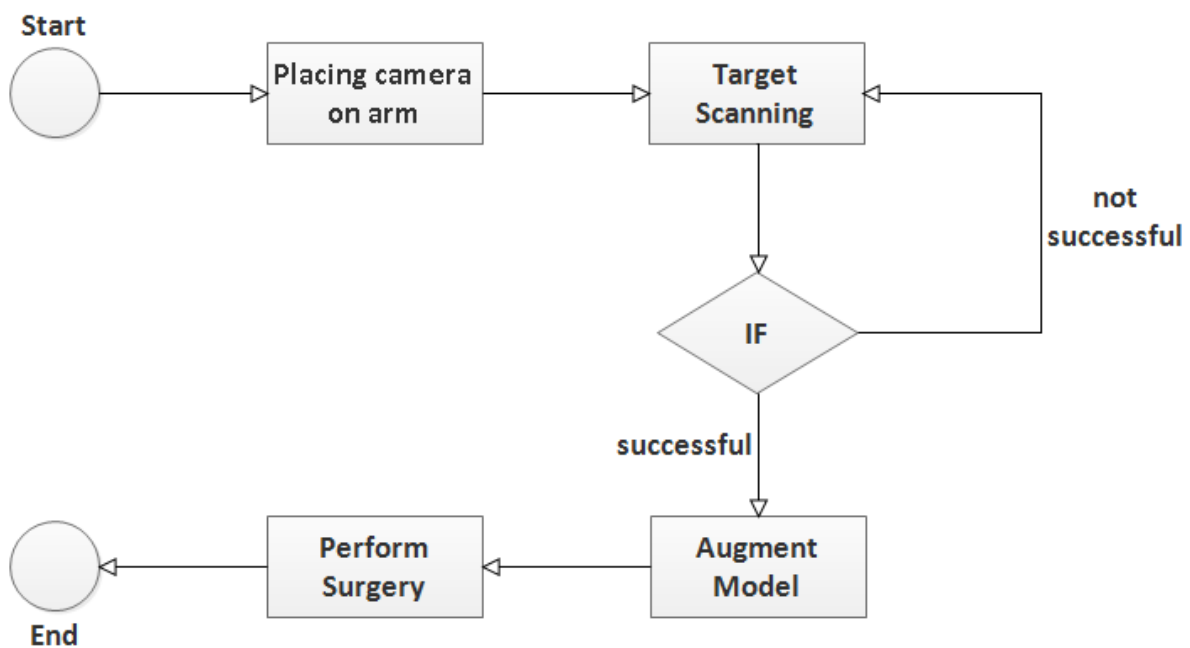


Fig 4.4 Activity diagram

4.5. Sequence Diagram

The sequence diagram shows the run time view of the application. It shows the detailed process interaction between different threads or processes of the application. The diagram provides clear view how the user will interact with the processes of the application and how these processes will respond to each application trigger.

Sequence diagram of the application in as follows:

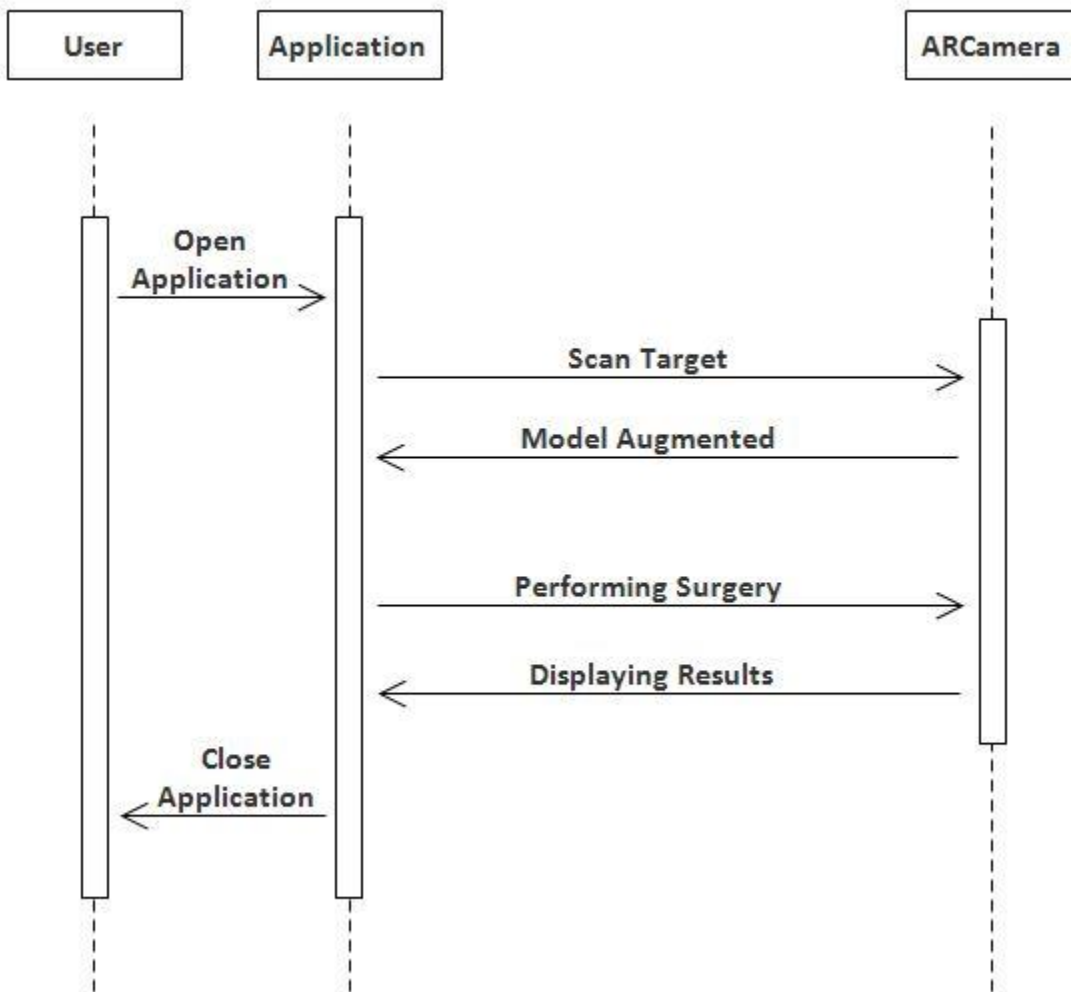


Fig 4.4 Sequence diagram of application

Sequence diagram of performing surgery is as follows:

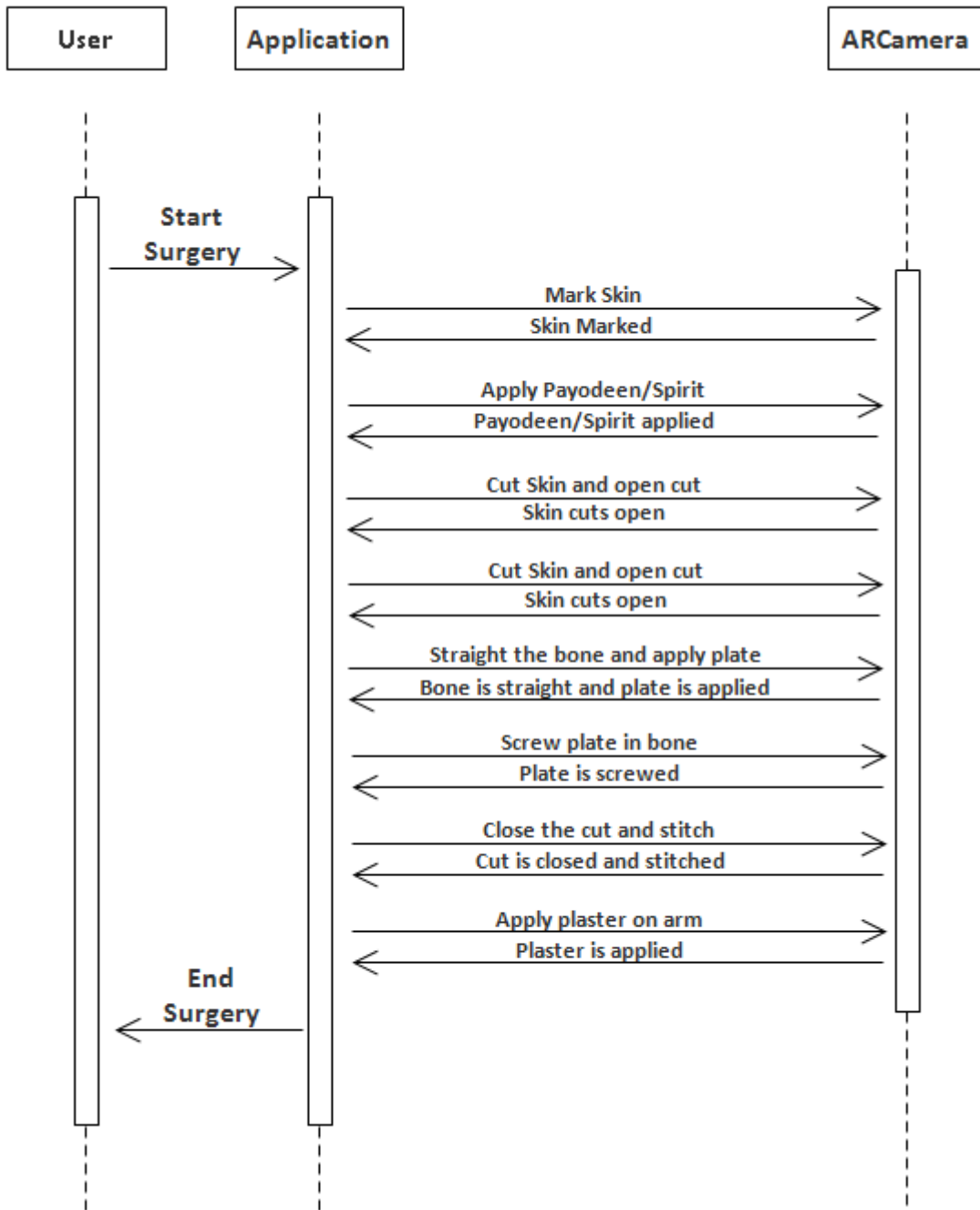


Fig 4.5 Sequence diagram of surgery

Chapter 5

System Implementation

The System implementation is an understanding of a technical specification or algorithm as a program, software component, or other computer system through programming and deployment. In this chapter system implementation is explained in detail. It includes explanation about tools and techniques used to complete this task, and also explanation about any algorithms used.

5.1. Tools and Technology

5.1.1. Unity 3D

Unity3D is a cross-platform 3D engine and a user-friendly development environment developed by Unity Technologies. Easy enough for the beginner and powerful enough for the expert; Unity should interest anybody who wants to easily create 3D games and applications for mobile, desktop, the web, and consoles [23].

5.1.2. MonoDevelop

MonoDevelop (also known as Xamarin Studio) is an open source integrated development environment for Linux, macOS and Windows. Its primary focus is development of projects that use Mono and .NET frameworks. MonoDevelop integrates features like Microsoft Visual Studio, such as automatic code compilation, source control, a graphical user interface (GUI) and Web designer. MonoDevelop integrates a Gtk# GUI designer called Stetic. It supports C, C++, C#, F#, Java etc. [24].

5.1.3. Blender

Blender is the free and open source 3D creation suite. Blender's features include 3D modeling, UV unwrapping, texturing, raster graphics editing, rigging and skinning, fluid and smoke simulation, particle simulation, soft body simulation, sculpting, animating, match moving, camera tracking, rendering, video editing and compositing [25].

5.1.4. Vuforia

Vuforia is an Augmented Reality Software Development Kit (SDK) for mobile devices that enables the creation of Augmented Reality applications.

The Vuforia SDK supports a variety of 2D and 3D target types including marker less Image Targets, 3D Multi-Target configurations, and a form of addressable Fiduciary Marker known as a Frame Marker. Additional features of the SDK include localized Occlusion Detection using 'Virtual Buttons', runtime image target selection, and the ability to create and reconfigure target sets programmatically at runtime [26].

It tracks "Image targets" and simple 3D objects, such as boxes, in real time. This allows developers to position virtual object, such as 3D models, in relation to real world images when these are viewed through the camera of a mobile device. It appears that the virtual object is a part of the real world scene. We are using the similar concept that our application detects the target placed over the palm of the hand and a 3D model of arm is augmented on the real arm. There is some limitations in the Vuforia SDK, it does not detect human body parts directly, that is why we are using a specific target for the project.

5.2. Development Environment / Language

Main development environment used in this project is Unity, using Vuforia SDK. Language that is used is C# for scripting in unity. MonoDevelop is used for writing scripts and Blender is used to make 3D and 2D models. Edraw Max is used for making diagrams which are used in project documentation.

5.3. Methodologies

We use agile model for the implementation of project so that we have room for improvements since with time, technology is advancing. When new changes are needed to be implemented, the freedom agile gives to change is very important. New changes can be implemented at very little cost because of the frequency of new increments that are produced. To implement a new feature, the developers need to lose only the work of a few days, or even only hours, to roll back and implement it [20]. Development of this project is completed in two phases:

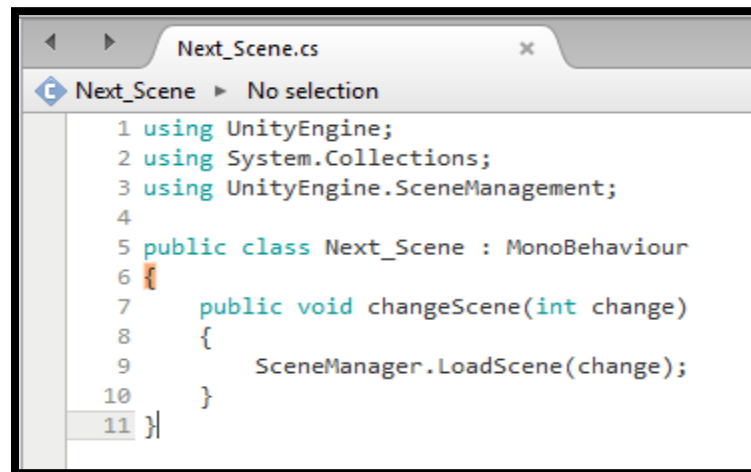
5.3.1. Phase I (Interface)

In the first phase, we designed and developed the interface of mobile application as well as the models used. These interfaces were designed under the standard guidelines of

Human Computer Interaction to ensure maximum user satisfaction as well as the development of most effective GUI. After the development of interface, we moved on to our next phase.

5.3.2. Phase II (Functionality)

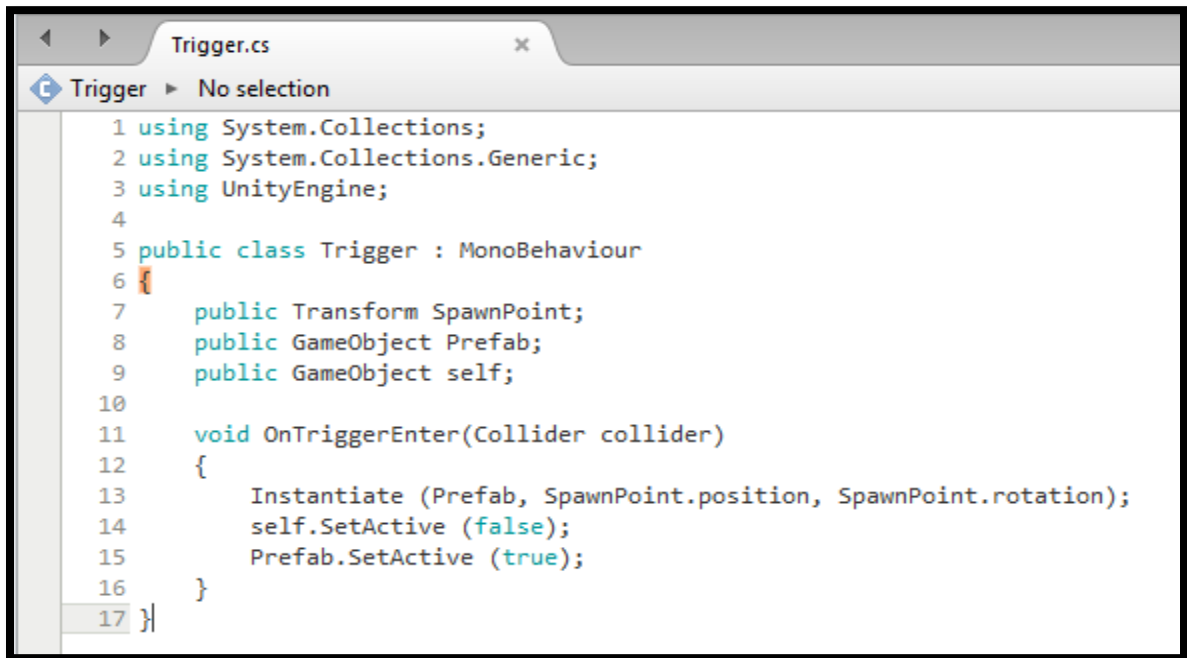
In this phase, the main functionality of the system is implemented. When application starts, main page is displayed which contains the project title, a patient and doctor image in the background, and a camera button which takes the user to the next scene. A next scene script is attached with the button. The snippet of the script is as follows:

A screenshot of a code editor window titled 'Next_Scene.cs'. The editor shows the following C# code snippet:

```
1 using UnityEngine;
2 using System.Collections;
3 using UnityEngine.SceneManagement;
4
5 public class Next_Scene : MonoBehaviour
6 {
7     public void changeScene(int change)
8     {
9         SceneManager.LoadScene(change);
10    }
11 }
```

Figure 5.1 Next scene script

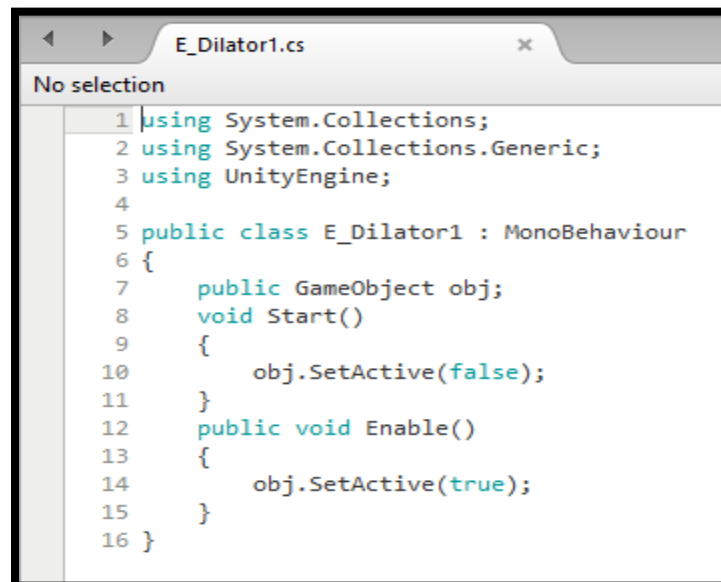
In the next scene or we called it the main scene of the project where application detects the target or pattern which is uploaded on Vuforia database and it converts it to a package which is easily include in the unity project. After augmentation of a model, surgery starts. The steps involved in the surgery are already discussed in the previous chapters. All the events are trigger based and the snippet of the script is as follows:



```
1 using System.Collections;
2 using System.Collections.Generic;
3 using UnityEngine;
4
5 public class Trigger : MonoBehaviour
6 {
7     public Transform SpawnPoint;
8     public GameObject Prefab;
9     public GameObject self;
10
11     void OnTriggerEnter(Collider collider)
12     {
13         Instantiate (Prefab, SpawnPoint.position, SpawnPoint.rotation);
14         self.SetActive (false);
15         Prefab.SetActive (true);
16     }
17 }
```

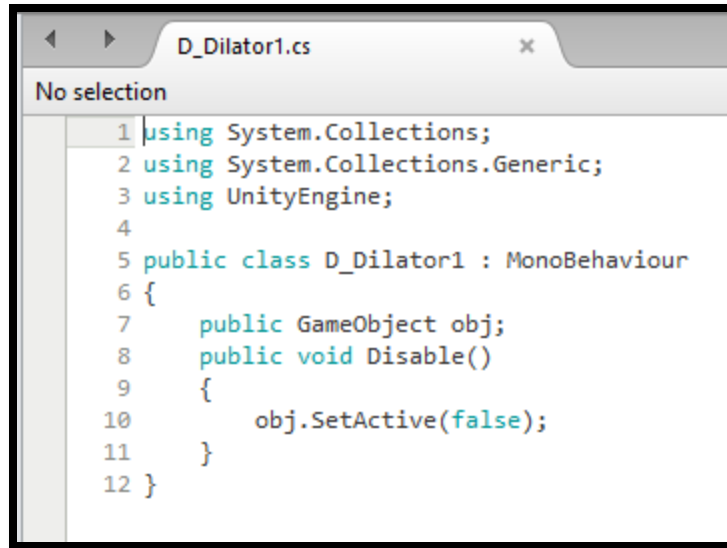
Figure 5.2 Event trigger script

Enabling and disabling properties are also used in the project which is applied on the tools used in the surgery. The snippet of the scripts are as follows:



```
1 using System.Collections;
2 using System.Collections.Generic;
3 using UnityEngine;
4
5 public class E_Dilator1 : MonoBehaviour
6 {
7     public GameObject obj;
8     void Start()
9     {
10         obj.SetActive(false);
11     }
12     public void Enable()
13     {
14         obj.SetActive(true);
15     }
16 }
```

Figure 5.3 Enable object/tool script



```
1 using System.Collections;
2 using System.Collections.Generic;
3 using UnityEngine;
4
5 public class D_Dilator1 : MonoBehaviour
6 {
7     public GameObject obj;
8     public void Disable()
9     {
10         obj.SetActive(false);
11     }
12 }
```

Figure 5.4 Disable object/tool script

In the end, a replay button appears which takes the control of application back to the main page. Instructions are also displayed for every step. While doing surgery, there is no going back from the current step to the previous one. User will have to pay attention while doing surgery.

Chapter 6

System Testing and Evaluation

This system is tested in an android device containing 6.0 (Marshmallow) android version. The device has 5.5 inch display and 1080x1920 resolution with 3GB RAM and Kirin 655 Octa-Core 4x 2.1 GHz + 4x 1.7 GHz processor.

6.1. Installation Testing

The application is installed in different android versions such as 4.0 (Ice Cream Sandwich), 4.1 (Jelly Bean) and 6.0 (Marshmallow). There was a clean install and no such error occurred. On the other hand this application is not for the users who are using android versions less than 4.0 (Ice Cream Sandwich). Now a days, no mobile phone company sell their product with old android versions as well as the existing applications are also not compatible with the old versions. With the advancement of technology, nobody likes to use old technology of old software, that is why this application is not designed for the previous and old android versions.

Table 6.1 Test case 1(a)

Test Case 1	Installation
Description	Application will be installed and have no error
Requirements	Android version must be greater than or equal to 4.0 (Ice cream Sandwich)

Table 6.2 Test case 1(b)

Tasks	Expected result	Actual result
Runs on Android 2.3 (Gingerbread)	Pass / Fail	Pass
Runs on Android 4.0 (Ice Cream Sandwich)	Pass / Fail	Pass
Runs on Android 4.1 (Jelly Bean)	Pass / Fail	Pass
Runs on Android 6.0 (Marshmallow)	Pass / Fail	Pass

6.2. Usability Testing

Table 6.3 Test case 1(a)

Test Case 1	Application startup
Description	The application displays the “Startup screen” when executed and let the user to scan the given target
Requirements	Application is installed on the android device

Table 6.4 Test case 1(b)

Tasks	Excepted result	Actual result
Application start	Pass / Fail	Pass
Start-up screen display	Pass / Fail	Pass

Table 6.5 Test case 2(a)

Test Case 2	Scan target
Description	Place camera over the target to scan the defined patterns
Requirements	Application was successfully executed and camera is in working state

Table 6.6 Test case 2(b)

Tasks	Excepted result	Actual result
Target Scan	Pass / Fail	Pass
3D arm model augmented	Pass / Fail	Pass

Table 6.7 Test case 3(a)

Test Case 3	Mark skin
Description	Drag the maker over arm skin to mark it for cut
Requirements	Touch (gestures) works properly

Table 6.8 Test case 3(b)

Tasks	Excepted result	Actual result
Drag and drop marker	Pass / Fail	Pass
Skin marked	Pass / Fail	Pass

Table 6.9 Test case 4(a)

Test Case 4	Apply payodeen/spirit
Description	Apply the sedatives over the augmented arm model by dragging the tool
Requirements	Touch (gestures) works properly

Table 6.10 Test case 4(b)

Tasks	Excepted result	Actual result
Sedatives applied	Pass / Fail	Pass

Table 6.11 Test case 5(a)

Test Case 5	Cut skin
Description	Drag the cutter/blade over arm skin to cut
Requirements	Touch (gestures) works properly

Table 6.12 Test case 5(b)

Tasks	Excepted result	Actual result
Drag and drop cutter/blade	Pass / Fail	Pass
Skin cut	Pass / Fail	Pass

Table 6.13 Test case 6(a)

Test Case 6	Open the cut
Description	Drag dilator into the cut to open it
Requirements	Touch (gestures) works properly

Table 6.14 Test case 6(b)

Tasks	Excepted result	Actual result
Drag and drop dilator	Pass / Fail	Pass
Cut open	Pass / Fail	Pass

Table 6.15 Test case 7(a)

Test Case 7	Straight the bone
Description	Drag another dilator towards the fractured bone to make it straight
Requirements	Touch (gestures) works properly

Table 6.16 Test case 7(b)

Tasks	Excepted result	Actual result
Drag and drop dilator	Pass / Fail	Pass
Bone become straight	Pass / Fail	Pass

Table 6.17 Test case 8(a)

Test Case 8	Apply plate
Description	Drag the plate from the tray over the bone
Requirements	Touch (gestures) works properly

Table 6.18 Test case 8(b)

Tasks	Excepted result	Actual result
Drag and drop plat	Pass / Fail	Pass
Plat placed on the bone	Pass / Fail	Pass

Table 6.19 Test case 9(a)

Test Case 9	Screw plate
Description	Screw the plate with the help of screwing tool
Requirements	Touch (gestures) works properly

Table 6.20 Test case 9(b)

Tasks	Excepted result	Actual result
Drag and drop screwing tool	Pass / Fail	Pass
Plate screwed	Pass / Fail	Pass

Table 6.21 Test case 10(a)

Test Case 10	Close the cut and stitch
Description	Stitch the cut with needle to close it properly
Requirements	Touch (gestures) works properly

Table 6.22 Test case 10(b)

Tasks	Excepted result	Actual result
Drag and drop needle	Pass / Fail	Pass
Cut closed and stitched	Pass / Fail	Pass

Table 6.23 Test case 11(a)

Test Case 11	Plaster the arm
Description	Apply plaster on the arm so that the fractured bone does not move
Requirements	Touch (gestures) works properly

Table 6.24 Test case 11(b)

Tasks	Excepted result	Actual result
Plaster applied	Pass / Fail	Pass
Surgery completed	Pass / Fail	Pass

6.3. Compatibility Testing

The application is compatible with the 4.0 (Ice Cream Sandwich) android version or higher. This application will not work for the users who are using android version less than 4.0.

Table 6.25 Test case 1(a)

Test Case 1	Compatibility testing
Description	Run the application on different android versions
Requirements	Android version must be greater than or equal to 4.0 (Ice cream Sandwich)

Table 6.26 Test case 1(b)

Tasks	Excepted result	Actual result
Android version 1.6 (Donut)	Pass / Fail	Fail
Android version 2.1 (Eclair)	Pass / Fail	Fail
Android version 2.2 (Froyo)	Pass / Fail	Fail
Android version 2.3 (Gingerbread) [Tested]	Pass / Fail	Fail
Android version 3.0 (Honeycomb)	Pass / Fail	Fail

Android version 4.0 (Ice Cream Sandwich) [Tested]	Pass / Fail	Pass
Android version 4.1 (Jelly Bean) [Tested]	Pass / Fail	Pass
Android version 4.4 (KitKat)	Pass / Fail	Pass
Android version 5.0 (Lollipop)	Pass / Fail	Pass
Android version 6.0 (Marshmallow) [Tested]	Pass / Fail	Pass
Android version 7.0 (Nougat)	Pass / Fail	Pass

Chapter 7

Conclusion

The project “**Augmented Forearm Fracture Surgery**” application is a successful effort and is about to help the user to learn how to perform a forearm fracture surgery. The main objective of this project is to provide a realistic view to learn the fracture surgery processes step by step.

After developing the project, we understand that what basically augmented reality is and how it works. How the augmented reality is implemented on mobile application. We have learned how the system testing is done on mobile application, specially applications in which augmented reality is involved.

7.1. Future Enhancement

In this project, application recognizes patterns which are drawn on the paper instead of human arm. The project can be enhanced by adding the functionality of recognizing the human arm directly. It will make the application more attractive and give more realist touch. By introducing a tool box, for instance instead of a fixed sequence of tools, user may be provided with a tool box from which user can pick an appropriate tool and warn in case of a wrongly picked tool. Some aspects can be more dynamic for instance the number of stitches.

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