Augmented Reality Exploration of Human Femur: Unveiling Fractures and Anatomy for Enhanced Understanding

BY

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ABSTRACT

This proposal introduces an innovative Augmented Reality (AR) application, "Augmented Reality Exploration of Human Femur," aimed at revolutionizing the understanding and analysis of femur fractures. Traditional methods of studying femur anatomy often lack the interactivity and precision needed for detailed exploration, which this AR application seeks to address. By integrating advanced AR technology with meticulously crafted 3D models, the application will allow medical professionals, educators, and students to virtually dissect and examine the femur in real-time, enhancing the comprehension of its complex structures and fractures. The development will be conducted using Unity, with Blender refining the 3D models for anatomical accuracy, and C# programming executed in Microsoft Visual Studio. Firebase will support data storage and management, facilitating user interactions and educational modules. The expected outcome is a user-friendly, immersive tool that sets new standards in medical education and clinical practice, improving diagnostic accuracy and treatment planning.

Area of Study (Minimum 1 and Maximum 2): Augmented Reality (AR)

Keywords (Minimum 5 and Maximum 10): Femur Fracture, Medical Education, Fracture Analysis, Augmented Reality (AR), AR in Healthcare

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LIST OF ABBREVIATIONS

AR	Augmented Reality
2D	2-Dimensional
3D	3-Dimensional
CT	Computed Tomography
NOF	Neck Of Femur
MR	Mix Reality
SLAM	Simultaneous localization and mapping

CHAPTER 1

Introduction

The foundation of this research is rooted in the critical intersection of technology and medical science, specifically focusing on the exploration of human femur fractures through Augmented Reality (AR). Fractures of the human femur pose significant challenges in diagnosis, treatment planning, and medical education [1]. Traditional approaches often lack the precision required for a thorough understanding of femur anatomy and fractures. The motivation for our research stems from the pressing need to address these challenges and leverage innovative technologies to enhance medical practices.

1.1 Problem Statement and Motivation

The medical field is confronted with a critical challenge in the diagnosis, treatment planning, and educational understanding of human femur fractures. Traditional approaches often fall short in providing the necessary precision to fully comprehend the complexities of femur anatomy and fractures, which can lead to suboptimal medical practices and patient outcomes [2]. This inadequacy underscores a pressing need for innovative solutions that can bridge the gap between medical science and advanced technology. Despite the increasing prevalence of femur fractures, there is a notable scarcity of dedicated tools and applications that enhance understanding and interaction with this vital aspect of human anatomy. This is particularly evident in the realm of Augmented Reality (AR), where the potential to create immersive and dynamic learning experiences remains largely untapped. The lack of advanced tools not only hampers precise diagnosis but also limits the availability of effective educational resources, thereby impeding the medical community's ability to address femur fractures efficiently.

Motivated by these challenges, this project seeks to develop an AR application that focuses specifically on femur anatomy and fractures, filling a crucial gap in the resources available for medical education. The proposed application aims to introduce AR interactivity to the study of femur fractures, allowing users to visualize and understand these fractures in three-dimensional space with an unprecedented level of detail and realism. By offering a hands-on experience, the application is designed to enhance comprehension, improve diagnosis, and support better treatment planning. Furthermore, recognizing the financial constraints faced by students and medical enthusiasts, the application will be developed as a free resource. This ensures wider accessibility, enabling a broader audience to benefit from the educational content, thereby revolutionizing the way femur fractures are studied and understood in both educational and clinical settings.

1.2 Objectives

Develop an Interactive AR Experience:

- **Real-Time Exploration:** Enable users to interact with detailed 3D models of femur fractures in real-time, providing a dynamic and immersive experience.
- **Comparative Analysis:** Enable users to compare different types of femur fractures side by side, helping them to understand the variations and implications of each fracture type.
- **Enhanced Visualization:** Provide high-resolution, interactive 3D visualizations of femur fractures to help users visualize the impact and progression of various fracture types.

Provide Comprehensive Bone Information:

- **Detailed Anatomy:** Offer extensive information about the femur bone's structure, including key features such as joints, attachments, and surface landmarks.
- **Fracture Mechanics:** Include educational content on how different fractures affect the bone's function and integrity.

Increase Application Coverage:

- **Diverse Fracture Types:** Incorporate a wide range of femur fracture types, from simple to complex, to cover various clinical scenarios.

1.3 Project Scope and Direction

The "Augmented Reality Exploration of Human Femur Fractures" project aims to address critical challenges in the diagnosis, treatment, and education surrounding femur fractures by leveraging Augmented Reality (AR) technology. Traditional methods often lack the precision needed for an in-depth understanding of femur anatomy and fractures, leading to less effective medical practices. This project seeks to bridge this gap by developing an AR application that offers a dynamic and immersive experience. Users will be able to interact with high-resolution 3D models of femur fractures in real-time, virtually dissect the bone, and explore its intricate structure and various fracture types. The application will provide comprehensive information on femur anatomy, including key features like joints and attachments, and educational content on fracture mechanics. By incorporating a wide range of fracture types, the application will cater to diverse clinical scenarios, enhancing both educational and diagnostic capabilities. Recognizing the financial constraints of students and medical enthusiasts, the application will be developed as a free resource, ensuring broader accessibility and impact. The project will utilize Unity for AR development, Blender for 3D modeling, and Microsoft Visual Studio with C# for programming. Comprehensive testing and user feedback will guide refinements, ensuring an effective and user-friendly tool that revolutionizes the study and understanding of femur fractures in medical education and clinical practice

1.4 Contributions

The project contributes significantly to the field of medical education and practice by addressing several key areas.
Firstly, Accessibility and Cost-Efficiency is a major contribution. The application is developed as a free resource, which addresses financial constraints faced by students and medical enthusiasts. This ensures broader accessibility and democratizes the availability of advanced educational tools, making high-quality learning resources available to a wider audience.

Enhanced Learning Experience is another crucial contribution. By integrating Augmented Reality (AR) technology, the project offers a dynamic and immersive learning experience. Users can interact with detailed 3D models of femur fractures in real-time, which enhances their understanding and retention of complex anatomical and fracture information.

The project also provides Advanced Visualization Tools. The application features high-resolution, interactive 3D visualizations of the femur and its fractures, allowing users to visualize and analyze fractures from various angles and perspectives. This improved visualization helps users better comprehend the impact and progression of different types of fractures.

Finally, the project supports Medical Education and Practice by filling a crucial gap in existing educational resources. It specifically focuses on femur fractures, providing a tool that aids in improved diagnosis, treatment planning, and medical education. This contributes to better patient outcomes and more effective medical training, addressing a significant need in the medical field.

1.5 Project Background

The foundation of this research is rooted in the critical intersection of technology and medical science, specifically focusing on the exploration of human femur fractures through Augmented Reality (AR). Fractures of the human femur pose significant challenges in diagnosis, treatment planning, and medical education. Traditional approaches often lack the precision required for a thorough understanding of femur anatomy and fractures. The motivation for our research stems from the pressing need toaddress these challenges and leverage innovative technologies to enhance medical practices.

1.6 Human Femur

Let's embark on a journey into the intricate realm of the human femur, the central protagonist of our project. Commonly referred to as the femoral bone, the human femur stands as the longest and strongest bone in the human body, forming a vital component of the skeletal framework. It is responsible for a couple important task for human being.

Foremost among its roles is the formidable task of bearing the weight of the entire body during both standing and movement, underscoring its significance in providing structural support. Beyond its load-bearing prowess, the femur plays a pivotal role in stabilization, acting as a steadfast anchor that ensures balance and equilibrium during various movements. Additionally, the femur acts as a vital connector, intricately linking muscles, tendons, and ligaments in the hip and knee regions to the broader physiological network of the body. This interconnected web of support facilitates coordinated movements and underscores the femur's indispensable contribution to the overall functionality of the human musculoskeletal system.

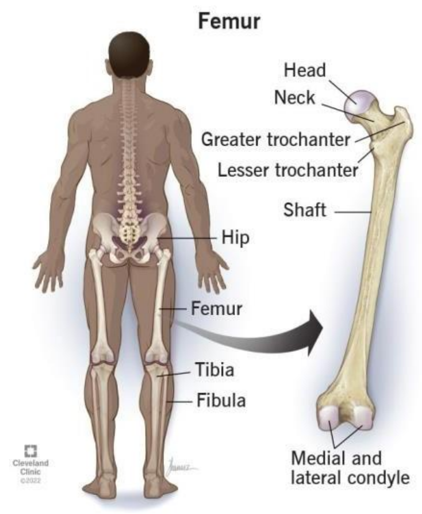


Figure 1.6-1 Location of Femur and its characteristic

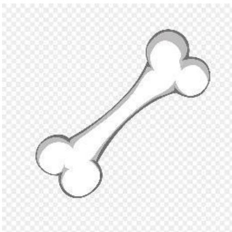


Figure 1.6-2 Bone Cartoon illustration

Human femur is the one and only bone located in our thigh, running from our hips to our knee. Based on figure 1.1.1-1, we can observe the outer structure of the of the femur. The outer structure of the femur exhibits a distinctive and robust composition, characterized by two rounded ends and a lengthy shaft in the middle, resembling the classic shape often depicted in cartoon illustrations—a cylindrical form with two rounded protrusions at each extremity (Figure 1.1.1-2) [1]. Despite its appearance as a singular elongated bone, the femur is intricately segmented into several key parts, each serving specific functions in maintaining the bone's structural integrity and supporting various physiological activities.

At the upper (proximal) end of the femur, which connects to the hip joint, lies the proximal aspect housing essential components such as the head, neck, greater trochanter, lesser trochanter, and the intertrochanteric line and crest. These elements collectively

contribute to the articulation and connection of the femur with the hip, forming a crucial junction for weight-bearing and mobility.

The long portion of the femur, known as the shaft, extends downward, supporting the body's weight and forming the structural framework of the thigh. This section features key anatomical landmarks, including the linea aspera, gluteal tuberosity, pectineal line, and popliteal fossa, all contributing to the bone's strength and functionality. The shaft angles slightly toward the center of the body, optimizing its role in weight distribution and movement.

The lower (distal) end of the femur constitutes the top of the knee joint, where it meets the tibia (shin) and patella (kneecap). This distal aspect includes crucial structures such asthe medial and lateral condyles, medial and lateral epicondyles, and the intercondylar fossa, forming pivotal connections that facilitate joint movements and ensure stability.

While these intricate parts and labels are typically employed by healthcare providers to describe specific areas of concern, such as pain or issues, they collectively contribute to a comprehensive understanding of the femur's outer structure. In instances of a femoral fracture, these terms become particularly relevant as healthcare professionals utilize them to precisely identify and communicate the location of bone damage for effective diagnosis and treatment.

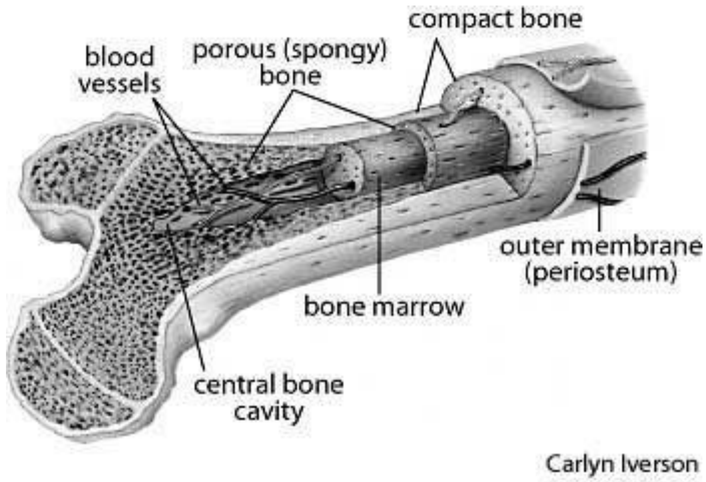


Figure 1.6-3 Anatomy of Femur

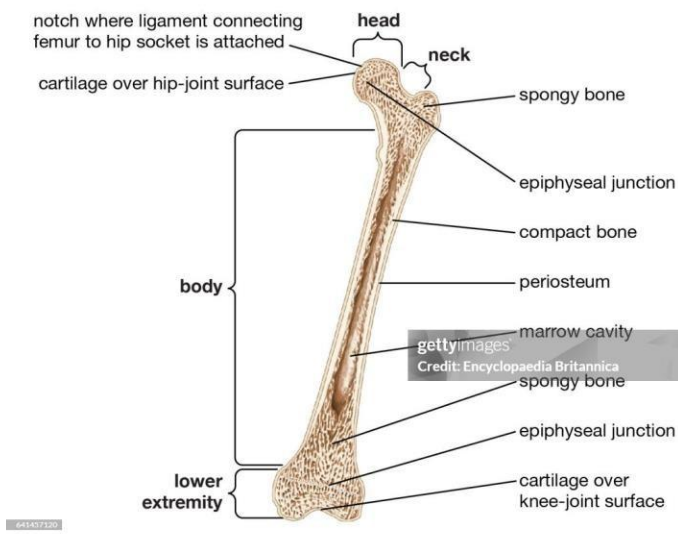


Figure 1.6-4 Side View of the cross-section of femur

This structural marvel encompasses three distinct layers, each playing a crucial role in the bone's function and resilience. At the outermost layer lies the periosteum, akin to the outside skin of the bone. This thin, whitish skin is densely packed with nerves and blood vessels, serving as a vital conduit that supplies the cells responsible for building the robust bone beneath.

Beneath the periosteum, the femur reveals its dense and rigid layer known as compact bone. Resembling a cylinder, this layer is exceptionally hard, requiring the precision of asaw during surgical procedures. The compact bone, resembling a honeycomb with myriad tiny holes and passageways, accommodates nerves and blood vessels. These intricate pathways ensure the supply of oxygen and nutrients to the bone, facilitating its essential functions. Remarkably, the compact bone does not experience pain despite its density, as it consists predominantly of calcium and minerals.

Upon cutting through the compact bone, the innermost layer, known as spongy bone marrow, is unveiled. This layer, encased within the medullary cavity—a central cavity within bone shafts—holds a gelatin-like substance. The medullary cavity is integral to the production and storage of yellow bone marrow, also known as adipose. In infants, the marrow appears red due to active blood cell formation within the cavities. This dynamic marrow contributes to the generation of red blood cells, white blood cells for immune response, and platelets for blood clotting

The harmonious interaction of these three layers, coupled with the intricate network of nerve signals and blood streams coursing between them, underscores the femur's remarkable biomechanics. Thigh bones, pound for pound, exhibit strength surpassing that of reinforced concrete. Within the femur, an intriguing feature known as the epiphyseal line marks a strip of relatively less dense bone in long bones, highlighting the dynamic nature of bone structure and growth

1.6.1 Causes of Femur Fractures

Femur fractures, being a serious and often traumatic injury, can be attributed to a range of causes, with the two most common factors being high-speed trauma and pre-existing bone diseases [2]. High-speed trauma scenarios, such as motor vehicle or motorcycle accidents, falls from significant heights, or injuries sustained during extreme or contact sports, place immense force on the femur, leading to fractures. The abrupt and forceful impact associated with these events can result in the femur succumbing to the intense mechanical stress, causing a break in its structural integrity.

On the other hand, pre-existing bone diseases contribute to femur fractures by compromising the strength and density of the bone. Conditions like tumors, Paget disease, bone cysts, and osteoporosis weaken the structural integrity of the femur, makingit more susceptible to fractures even under normal or less severe circumstances. In the case of osteoporosis, the gradual loss of bone density over time renders the femur more prone to fractures, particularly in individuals with advanced age.

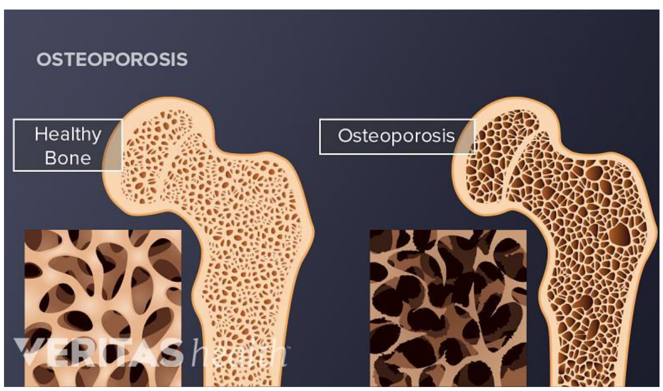


Figure 1.7.1-1 Differences between Healthy Bone and Osteoporosis Bon

1.7 Types of Femur Fractures

1.7.1 Femoral Shaft Fractures

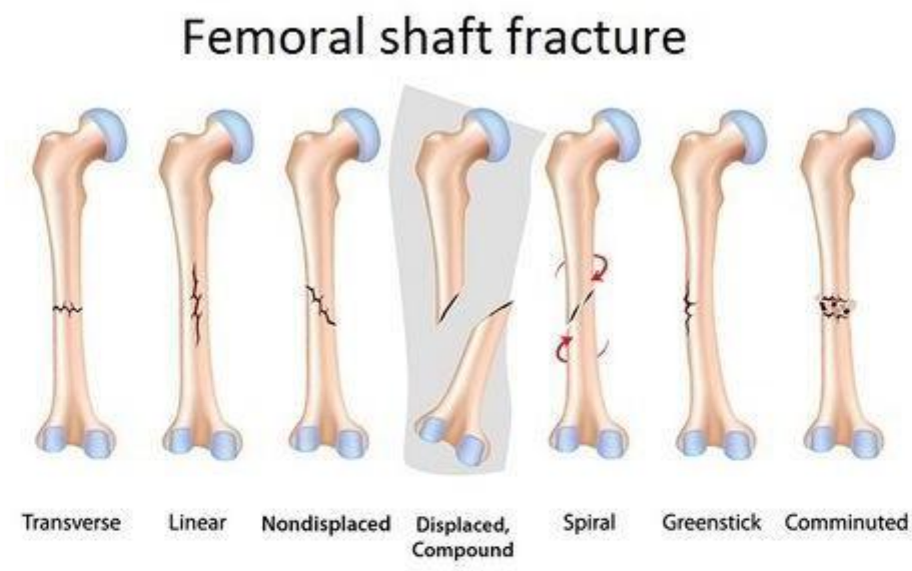


Figure 1.7.1-1 Different types of Femoral Shaft Fractures

Femoral shaft fractures exhibit a diverse array of patterns, each offering unique insights into the nature and magnitude of the forces that lead to such injuries.

One of the most common femoral shaft fractures is Transverse fractures, characterized by a straight horizontal break, typically result from direct forces appliedperpendicular to the femur's longitudinal axis.

On the other hand, oblique fractures showcase an angled line along the shaft,indicating the influence of angular forces during the traumatic event. The distinctive candy cane-like appearance of spiral fractures signifies a rotational or twisting force impacting the thigh.

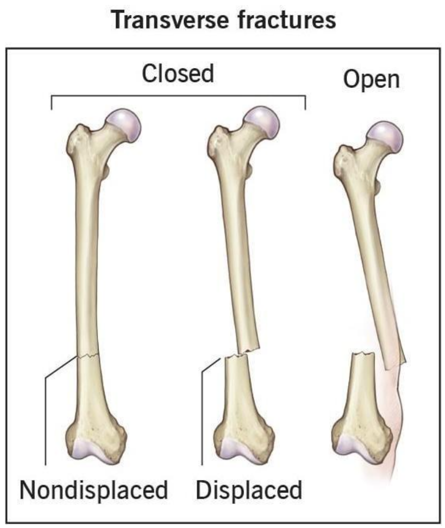
Comminuted fractures, with the bone fragmenting into multiple pieces, oftensignify high-energy trauma, emphasizing the severity of the applied force.

After that, Linear fractures in the femoral shaft occur when there is a straight, horizontal break across the bone. The line of the fracture runs perpendicular to the longaxis of the femur. These fractures can result from a direct impact or force applied to thefemur.

Besides, Greenstick fractures are incomplete fractures, common in pediatric populations where bones are more flexible. In a greenstick femur fracture, the bone is bent, causing a crack on one side while the other side remains intact. This type of fractureresembles the way a green twig breaks, hence the name.

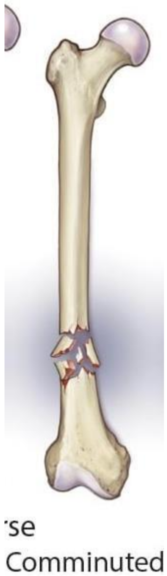
Among these, open or compound fractures present a particularly intricate scenario, where a bone fragment breaches the skin or a wound extends to the fractured site. Such fractures involve heightened complexity, as the risk of complications, especially infections, is elevated, demanding thorough clinical attention. Recognizing and understanding the nuances of these femoral shaft fractures is essential for orthopedic practitioners to tailor effective treatment plans, ensure optimal patient outcomes, and advance the field's knowledge in fracture biomechanics.

Table 1.8.1-1 Types of Common Fractures

Transverse Fractures  Figure 1.7.1-2 Transverse Fracture (a)  Figure 1.7.1-3 Transverse Fracture (b)	• Complete Fractures • Straight horizontal break • Cause by direct Forces • Applied perpendicularly

Oblique Fractures  Figure 1.7.1-4 Oblique Fractures (a)  Figure 1.7.1-5 Oblique Fractures (b)	• Complete Fracture • Angled line along the shaft • Cause by angular forces

Spiral Fractures  Figure 1.7.1-6 Spiral Fractures (a)  Figure 1.7.1-7 Spiral Fractures (b)	• Complete Fracture • helical or corkscrew-shaped break pattern that encircles the bone • Caused by twisting or rotational force applied to a bone

Comminuted Fractures  Figure 1.7.1-8 Comminuted Fractures (a)  Figure 1.7.1-9 Comminuted Fractures (b)	• Complete Fracture • The bone is broken into several pieces • Cause by severe trauma such as vehicle accidents or high fall

Linear Fractures  Figure 1.7.1-10 Linear Fractures (a)  Figure 1.7.1-11 Linear Fractures (b)	• Incomplete Fracture • straight, non-displaced break in the bone • Caused by direct trauma or force applied to the bone

Greenstick Fractures  Figure 1.7.1-12 Greenstick Fractures (a)  Figure 1.7.1-13 Greenstick Fractures (b)	• Incomplete Fracture • A partial break in the bone, causing it to bend • Caused by trauma or injury

Open Fractures  Figure 1.7.1-14 Open Fractures	• Complete Fracture • broken bone penetrates through the skin, exposing the fracture site to the external environment. • Caused by high-impact injuries, severe trauma, or accidents, such as car crashesor falls from significant heights.

1.7.2 Neck of Femur (NOF) Fractures

The femoral neck, being the slender region connecting the femoral head to the shaft, is recognized as the femur's weakest segment [3]. The implications of fractures in this critical area extend beyond the structural compromise, as they directly impact the blood supply to the femoral head, carrying substantial morbidity risks. Accurate diagnosis and classification of femoral neck fractures become paramount in navigating the complexities of their management. These fractures are broadly categorized into three types based on their anatomical locations:

Subcapital Fractures: Situated at the femoral head/neck junction, subcapital fracturesmark a crucial area where the integrity of the femoral neck is compromised.

Transcervical Fractures: Manifesting in the midportion of the femoral neck, transcervical fractures pose distinct challenges, necessitating tailored approaches in diagnosis and treatment.

Basicervical Fractures: Positioned at the base of the femoral neck, basicervical fractures add another layer of complexity to the classification spectrum. While debate persists in the literature regarding their precise categorization as intracapsular or extracapsular, prevailing wisdom often leans toward treating them as extracapsular fractures.

Table 1.1.4-1 Major Types of NOF Fractures

Subcapital: femoral head/neck junction

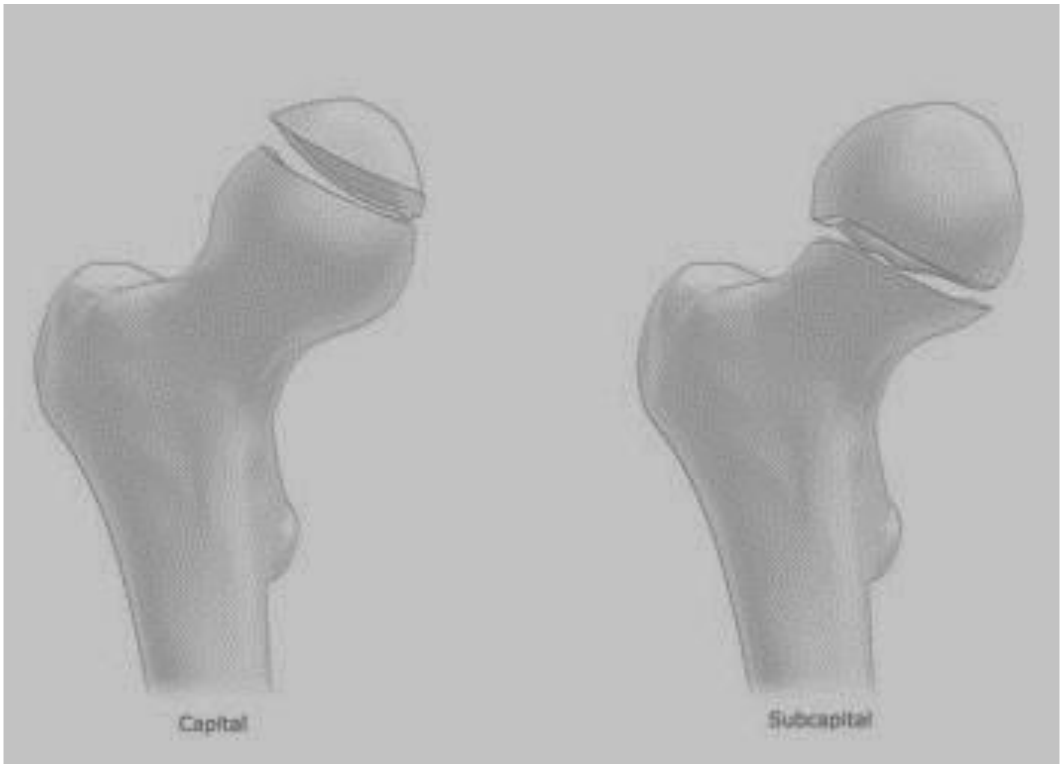


Figure 1.7.2-1 Subcapital (a)

Figure 1.7.2-2 Subcapital (b)

Transcervical: midportion of femoral neck

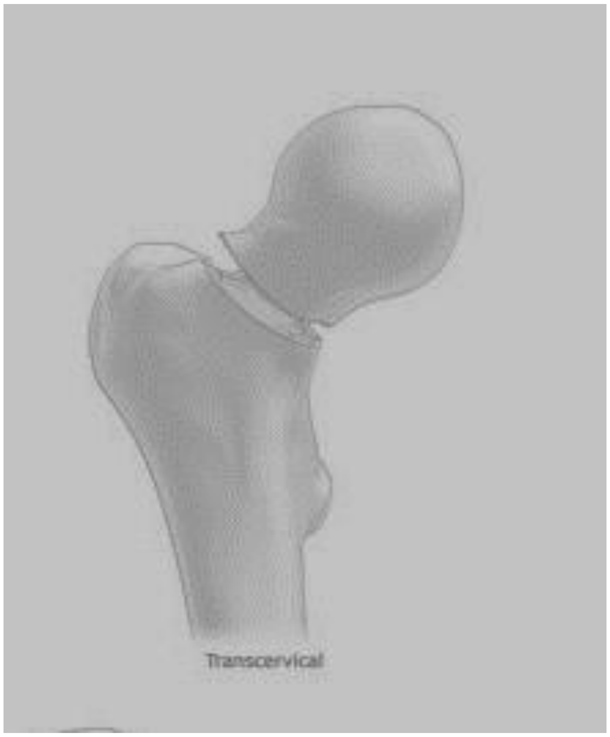


Figure 1.7.2-3 Transcervical (a)

Figure 1.7.2-4 Transcervical (b)

Basicervical: base of femoral neck

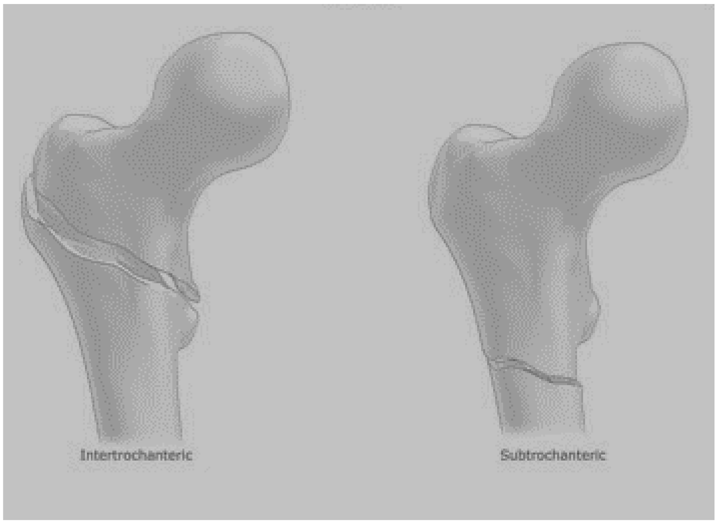


Figure 1.7.2-5 Basicervical (a)

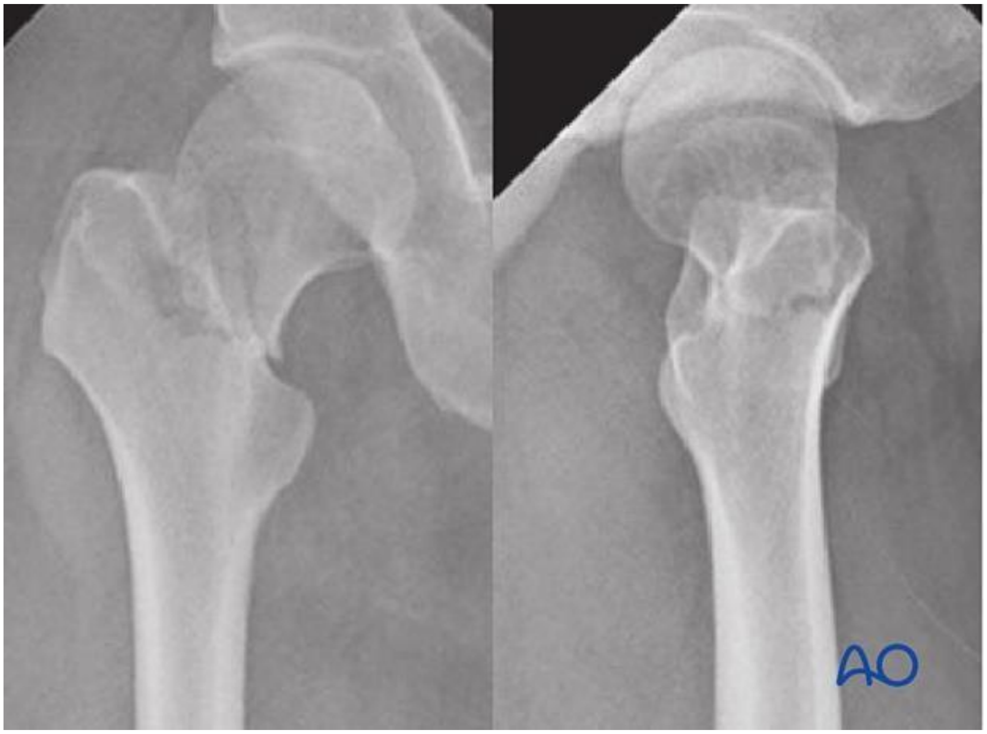


Figure 1.7.2-6 Basicervical(b)

1.8 Report Organization

The report outlines a project developing an Augmented Reality (AR) application for studying femur fractures. Chapter 1 introduces the problem and motivation behind the project, sets objectives, defines the project's scope and direction, and highlights contributions such as enhanced accessibility and learning experiences. Chapter 2 reviews existing AR applications and technology in healthcare, assessing their impact and relevance. Chapter 3 details the proposed method, including system requirements, design diagrams, and a project timeline. Chapter 4 presents preliminary work, covering software setup and initial results. Finally, Chapter 5 concludes with a summary of findings and future direction.

CHAPTER 2

Literature Reviews

2.0 Augmented Reality in HealthCare

Augmented Reality (AR) has emerged as a transformative technology that enriches the real-world environment with digital overlays, creating interactive and immersive experiences [3]. By seamlessly integrating virtual elements like images, sounds, and other sensory stimuli into the physical world through holographic technology, AR offers a dynamic interaction that blurs the lines between the digital and tangible realms. Its defining features include the coexistence of digital and physical worlds, real-time interactivity, and precise 3D identification of virtual and real objects. In recent years, AR has made significant strides in healthcare, reshaping the industry's landscape.

Augmented Reality (AR) is reshaping healthcare, offering innovative solutions across various medical realms [4]. Its impact is profound, enhancing medical imaging precision, transforming education and training, and improving patient outcomes.

2.0.1 Key Uses of AR in Healthcare

Surgical Assistance: AR enables surgeons to create 3D models of patient organs or tumors, providing real-time holographic guidance during surgery. Surgeons benefit from superimposed directions, minimizing errors.

Remote Guidance: In complex cases, doctors leverage live video calls and audio headsets for expert opinions. Specialists remotely guide doctors through procedures, fostering better treatment.

Medical Training: AR facilitates immersive training for medical practitioners and students. Remote mentors provide guidelines, improving skills and knowledge in real- time.

Diagnosis and Imaging: AR aids in 3D annotations and remote visual assistance for accurate patient diagnoses. Full-body scans visualize symptoms, reducing the need for extensive personal protective equipment.

Telehealth Advancements: The growth of telehealth is accelerated by AR, allowing remote consultations with augmented views of patients. Physicians use AR overlays for examinations, diagnoses, and guidance.

Vein Visualization: AR handheld scanners and near-infrared imaging assist in visualizing veins for blood collection, improving the success rate of injections.

2.0.2 Impact of AR in Healthcare:

Enhanced Medical Imaging:

An Augmented Reality (AR) based navigation system for surgical operations works by overlaying digital information onto the real-world environment, specifically tailored to assist in surgical procedures [5].

Enhance Remote Guidance:

utilizes a head-mounted display to enable mentors to view real-time video streams of surgical procedures from the trainees' side. The AR system provides a 3D visualization of the surgical scene, offering a more intuitive and immersive experience compared to traditional 2D video or text-based communication [6].

Medical Education and Training:

AR revolutionizes medical education by providing interactive learning experiences. Surgeons and medical students use AR simulations for surgical practice and anatomical exploration [7].

Seamless Hospital Navigation:

AR wayfinding applications simplify hospital navigation, providing step-by-step directions and floor plans for patients, visitors, and medical staff.

Empowering Physical Therapy:

AR offers interactive exercises and visual feedback for physical therapy and rehabilitation, improving patient engagement and therapy outcomes.

Robotic-Assisted Surgery:

AR enhances the precision of robotic-assisted surgeries by providing real-time overlays of critical information, guiding surgeons and improving surgical outcomes.[8]

2.1 Technological Review

2.1.1 Review of AR types

An AR visualization application for fractures of the neck of the femur has been developed specifically for Mixed Reality (MR), necessitating the use of a headset such as Microsoft's HoloLens [8]. However, the cost of such headsets is prohibitive, and their convenience in most scenarios is limited. Therefore, it would be advantageous to create such an application for a more universally accessible device—mobile phones. But first let’s determine which type of AR tracking we are planning to implement. There are many types of AR that can be implemented, some of them are Markers-Based, Location-Based, World- based or SLAM, and Body Tracking [9].

Marker Based AR are a very commonly used for developing AR in application [10]. Due to its simplicity in implementing and its higher accuracy in position. By linking each virtual product to a specific marker, the algorithm in the AR SDK will extract the geomatic features from a given marker and match it to the corresponding product. Then the marker will act as a reference for the display of the virtual object in the screen

The next AR we are going to talk about is Location-Based AR. This form of AR enables virtual objects to be anchored in the real world based on points of interest using GPS or geolocation data. One notable and popular example of a Location-Based AR application is Pokémon GO [11]. In this game, players explore their physical surroundings, and the game dynamically overlays virtual Pokémon and game elements ont o the real- world map, creating an immersive and interactive experience tied to specific locations.

Up next, World-Based or SLAM AR detects visually distinct features in the captured camera image called feature points and uses these points to compute its change in location. By aligning the pose of the virtual camera that renders your 3D content with the pose of the device's camera. Virtual content able to be render in the correct perspective. By using the following formula to remove white noise in non-edge regions for each raw depth image, bilateral filter is first applied [12].

$$I'(x) = \frac{1}{W} \sum_{y \in N(x)} e^{\frac{-\|y-x\|^2}{2\sigma_a^2}} e^{\frac{-|I(y)-I(x)|^2}{2\sigma_b^2}} I(y),$$

$$W = \sum_{y \in N(x)} e^{\frac{-\|y-x\|^2}{2\sigma_a^2}} e^{\frac{-|I(y)-I(x)|^2}{2\sigma_b^2}}.$$

Figure 2.1.1-1 Calculation for Depth

Then the initial pose estimation, accelerometer is used to measure the rotation of the mobile device by the following equations:

$$\varphi = \arctan2\left(\frac{Gx}{\mathrm{sign}(Gz)\sqrt{G_y^2 + G_z^2}}\right),$$

$$\theta = \arctan\left(\frac{Gy}{\sqrt{G_x^2 + G_z^2}}\right),$$

$$R_i = R(\varphi)R(\theta).$$

Figure 2.1.1-2 Calculation for Estimation of Device

In simple term, it means that the algorithm will first generate an environmental map, then is will determine the location of the device inside the environment [13].

Last but not least, Body tracking in augmented reality (AR) refers to the ability of AR systems to recognize and track the movements and positions of a user's body in real- time. This technology enables the overlay of virtual objects or information onto the user's body, creating interactive and immersive experiences. Body tracking AR can be applied in various contexts, from entertainment and gaming to fitness and healthcare [14]

Table 2.1.1-1 Types of AR

Types of AR	Necessary to generate tracker beforehand	Complexity
Marker Based AR	／	Simple
Location-based AR	×	Simple
World tracking/ SLAM	×	Intermediate
Body tracking AR	×	Intermediate

2.1.2 Review of AR SDK

There are a few AR Software Development Kit (SDK) available can be used to develop in Android Operating System (OS), Each of them is Unity AR Foundation, Vuforia by PTC and ARCore. All of these SDK can be integrated into Unity Engine which is perfectfor this project since it was built on Unity Engine.

Table 2.1.2-1 ARSDK

Unity AR Foundation Unity AR Foundation	• AR Foundation is a package that lets you build cross-platform AR applications in Unity3D. • you can develop your AR application in Unity3D and then build it either for Android or iOS. • Vast community support, easy access to Unity3D codebase & asset store if your project generates more than $100K over year, Unity3D Pro license will costyou from $40 to $150 per month.

Vuforia	• one of the oldest AR companies on the market • Vuforia Engine has been directly integrated with Unity3D, making it easier to create AR projects directly inside the game engine. • Vuforia developers were able to create a medical AR application that took a patient's 3D-printed heart as a marker model and built several layers of anatomy over it • Pricing is higher compared to other AR tools. The subscription starts at $42 / month. However, you can develop for free until the app is deployed.

ARCore	• ARCore was primarily focused on Android as the main platform for creating AR experiences. This target was only natural, given that both were developed by Google. • offers three main features: Motion Tracking, Environmental Understanding and Light Estimation • Free

2.2 Review of Previous Application

Similar application is AR anatomy by Virtual medicine, s.r.o., Skeleton by Catfish Animation Studio, Complete Anatomy 2023 by 3D Human Body Atlas & Courses and also Anatomyka Skeleton by Woodoo Art s.r.o

2.2.1 AR anatomy

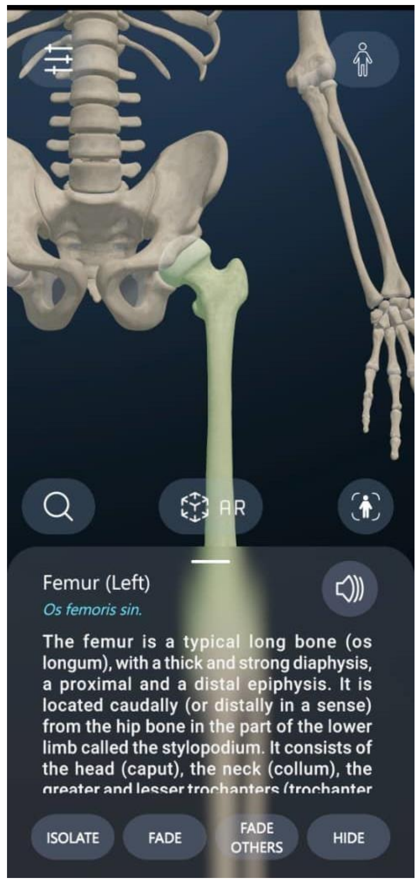


Figure 2.2.1-1 AR Anatomy Menu Figure 2.2.1-2 AR Anatomy Description of Bones

Figure 2.2.1-3 AR Anatomy in AR View

Figure 2.2.1-4 AR Anatomy Selected Femur

Figure 2.2.1-5 AR Anatomy Isolate Femur

AR Anatomy presents a comprehensive educational package tailored for a seamless learning experience across various devices, including mobile phones, tablets, and desktop or laptop computers. This educational tool encompasses detailed representations of all human body systems, such as skeletal, muscular, nervous, cardiovascular, respiratory, digestive, reproductive, lymphatic, and connective tissues. The package goes beyond static representations, providing users with multiple interactive functions, including the ability to combine, layer, and highlight specific anatomical features. One of the standout features of AR Anatomy is its advanced Augmented Reality (AR) Mode, which empowers users to position a detailed human body model directly into their real-world environment. This mode enhances the learning experience by allowing users to interact with anatomical structures in a tangible and immersive way. For educational institutions such as universities and secondary schools, AR Anatomy offers a Cross-platform Multi-User collaboration mode. This feature enables lecturers to conduct virtual classes where students can connect to the teacher's online lecture. The collaborative environment includes real-time video streaming and voice transmission, creating an engaging and interactive learning atmosphere for all connected students.

What sets AR Anatomy apart is its commitment to accessibility. Even without a Virtual Reality (VR) headset, users can still benefit from the augmented reality mode. This feature enables the placement of anatomical models directly into the user's real-world environment, providing a 3D perspective of more than 13,000 structures and animations. Each anatomical element is accompanied by detailed descriptions, making this a comprehensive educational resource that fits right in your pocket—accessible anytime and anywhere.

In essence, AR Anatomy revolutionizes anatomy education by combining cutting-edge technology with detailed anatomical representations, fostering an immersive and interactive learning experience for students and educators alike.

PROS

This application boasts robust support for marker less Augmented Reality (AR), allowing users to deploy AR experiences seamlessly in any environment without the need for specific markers. This flexibility enhances the user experience, enabling the application to be used effortlessly in diverse settings.

Notably, the application goes beyond traditional AR functionalities by offering the capability to isolate and interact with 3D models. This means users can not only visualize but actively engage with anatomical structures, providing a hands-on and immersive learning experience.

A standout feature that distinguishes this application from similar ones is its support for multiple user collaboration mode in AR. This collaborative environment enables users to connect and participate in real-time collaborative sessions. In an educational setting, for instance, this mode allows a lecturer to conduct virtual classes where students can simultaneously view, interact with, and discuss anatomical models. The inclusion of real-time video streaming and voice transmission fosters a dynamic and interactive learning atmosphere, setting this application apart in the realm of collaborative AR experiences.

CONS

One notable limitation of the application is the absence of a note-taking feature, which hinders users from documenting their insights or additional information during the learning process. This deficiency can be a drawback for users who wish to personalize their learning experience by recording specific observations, questions, or annotations related to anatomical structures.

Additionally, when isolating a particular part for focused study, the available information appears to be brief and general. The lack of specific details and comprehensive information about the selected part may limit the depth of understanding for users seeking more detailed insights into anatomical components. Moreover, the inability to select or choose the name and characteristics of the part could hinder users from accessing specific details crucial for a thorough understanding of anatomy.

2.2.2 Skeleton

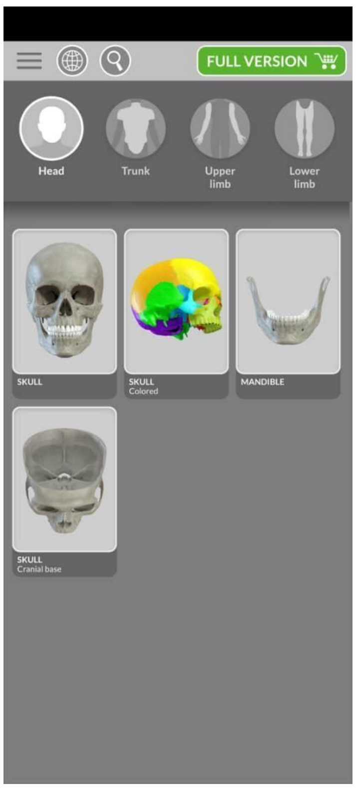


Figure 2.2.2-1 Skeleton Menu

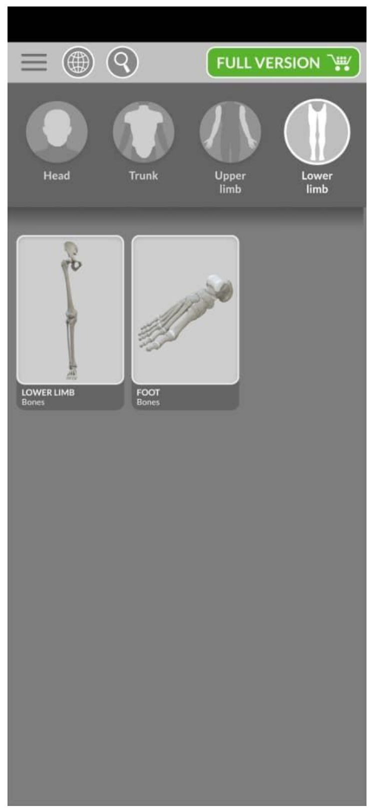
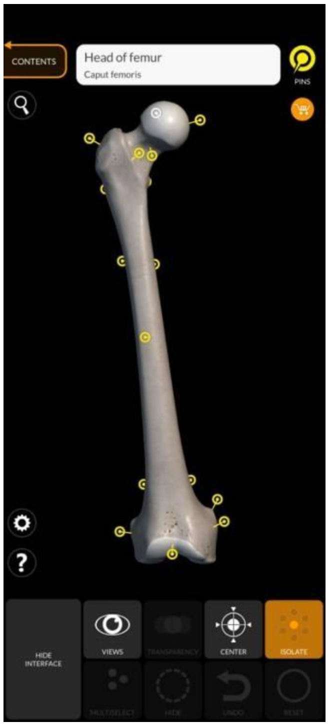


Figure 2.2.2-2 Skeleton Lower Limb Menu

Figure 2.2.2-3 Skeleton 3D view

Figure 2.2.2-4 Skeleton Femur Selected



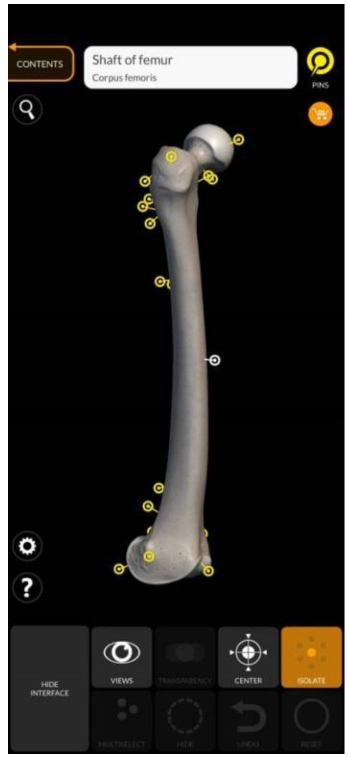


Figure 2.2.2-5 Skeleton Femur Isolated   Figure 2.2.2-6 Skeleton Shaft of Femur Selected

"Skeleton - 3D Atlas of Anatomy" stands as a revolutionary resource in the realm of anatomy education, offering an immersive and interactive experience through its advanced features. This next-generation anatomy atlas delves into the intricacies of the human skeleton, presenting users with highly detailed 3D anatomical models. The ability to effortlessly rotate and zoom in on each bone provides a dynamic exploration, allowing users to observe anatomical structures from any angle. With surfaces of the skeleton boasting textures of up to 4K resolution, the visual fidelity enhances the depth of understanding.

Navigating this comprehensive atlas is made simple and intuitive, empowering users to explore with ease. The division of anatomical regions ensures a clear and immediate visual grasp of each structure, while the option to hide individual bones facilitates focused study. Intelligent rotation streamlines navigation by automatically adjusting the center of rotation.

The Interactive Pin feature is a standout, enabling users to access terms related to specific anatomical details, enriching the learning experience.

The multi-language support of "Skeleton" caters to a diverse audience, with 11 languages available, including Latin, English, French, German, Italian, Portuguese, Russian, Spanish, Chinese, Japanese, and Korean. Users have the flexibility to select their preferred language directly from the app interface.

PROS

Within "Skeleton - 3D Atlas of Anatomy," each specific part of the human skeleton is thoughtfully equipped with an interactive pin feature. This unique functionality empowers users to select and explore individual anatomical components, unraveling a wealth of information about each part. By engaging with these pins, users can conveniently access and unveil the precise names associated with different anatomical structures.

The clarity and realism of the 3D models within the application are noteworthy. Crafted with meticulous attention to detail, the anatomical representations are not only visually clear but also remarkably realistic. Users can expect a lifelike and immersive experience as they delve into the intricacies of the human skeleton. The advanced rendering capabilities bring each bone to life, allowing users to gain a comprehensive understanding of the skeletal system with unparalleled clarity

CONS

While "Skeleton - 3D Atlas of Anatomy" offers an impressive interactive pin feature allowing users to select specific parts of the human skeleton, there are notable areas that could benefit from improvement. When a bone is selected, the current interface lacks detailed information and fails to distinctly highlight the chosen area within the 3D model.

This absence of clear visual indication may potentially lead to confusion for the user, as they may struggle to correlate the named part with its exact location on the anatomical model.

Moreover, the application currently lacks a note-taking feature, depriving users of the ability to personalize their learning experience by jotting down observations, questions, or additional information related to specific anatomical structures. The inclusion of a note-taking capability would significantly enhance the educational value of the app, allowing users to engage more deeply with the content and tailor their learning journey to individual preferences.

2.2.3 Complete Anatomy 2023

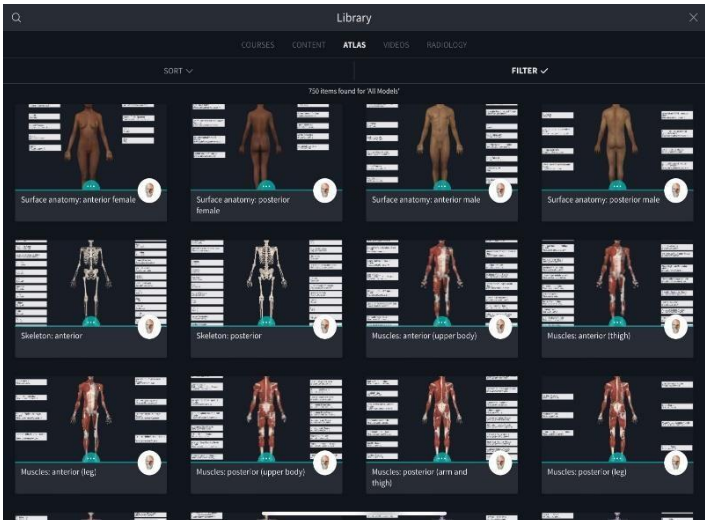


Figure 2.2.3-1 Complete Anatomy

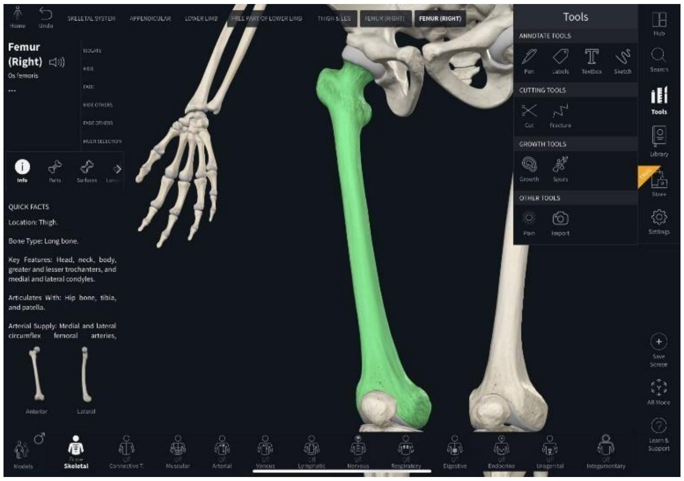


Figure 2.2.3-2 Complete Anatomy Femur Selected

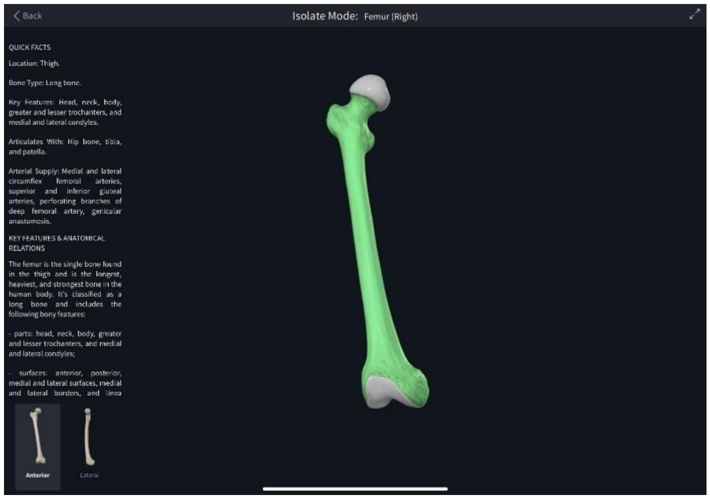


Figure 2.2.3-3 Complete Anatomy Femur Learning

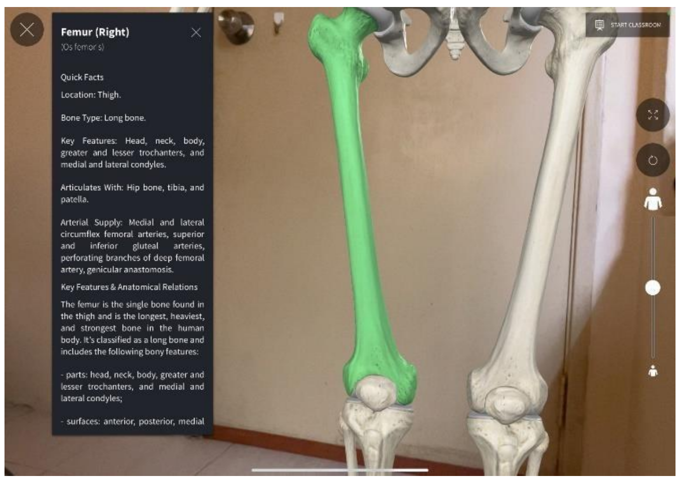


Figure 2.2.3-4 Complete Anatomy AR View

Complete Anatomy 2023" by 3D4Medical stands as a cutting-edge and comprehensive anatomy application, offering a wealth of features that cater to a diverse audience of medical professionals, educators, and enthusiasts. The application boasts highly detailed gross 3D anatomy models that provide users with a realistic and immersive exploration of the human body.

PROS

Notably, the application provides label viewing tools, allowing users to delve into the detailed nomenclature associated with different anatomical structures. Enhancing personalization, the inclusion of text box sketching enables users to annotate and highlight specific areas directly on the 3D models, fostering a more interactive and engaging learning environment. The inclusion of microscopic anatomy further enriches the educational content, offering insights into cellular and tissue-level structures.

One of the standout features of the application is its accessibility across all devices, ensuring users can seamlessly access its content on various platforms. Drawing inspiration from the esteemed Gray's Anatomy, the app's atlas provides accurate representations of human anatomy. With an extensive library encompassing over 1,500 videos and more than 100 courses, learners have access to a diverse range of educationalresources.

"Complete Anatomy 2023" stands out with dynamic cross sections, allowing users to explore anatomical structures layer by layer, and interactive radiology images that enhance the diagnostic aspect of the application. The inclusion of licenses for in-person presentations, patient education, and online/video call presentations reflects its versatility in catering to different educational settings.

Another one of the groundbreaking features of this application is its capability to simulate dissections virtually. Users can explore internal anatomy dynamically, gaining a comprehensive understanding of anatomical relationships. Taking it a step further, the application introduces an innovative bone fracture simulation, allowing users to visualize and comprehend the effects of bone fractures—an invaluable tool for medical education and pathology exploration.

CONS

One notable drawback of the "Complete Anatomy 2023" by 3D4Medical is its high price point, presenting a potential barrier for many students who may find it challenging to afford such an investment. While the application offers a wealth of features, including various anatomical systems and cutting-edge tools, the cost may limit accessibility for a significant portion of the student population.

The price factor could be a major concern, especially for students who are often operating within tight budgets. Access to comprehensive educational resources, particularly in the field of medicine and anatomy, is crucial for effective learning. The high cost may unfortunately restrict the app's availability to a narrower demographic, potentially excluding those who could benefit most from its advanced features.

Table 2.3-1 Comparison between Similar Application

Applications Functions	AR Anatomy	Skeleton	Complete Anatomy 2023	Proposed Application
AR Types	Marker-Less AR	Not Implemented	Marker-Less AR	Marker-Less AR
Able to make Notes	✗	✗	✓	✓
Information and Labeling	✓	✗	✓	✓
Extra Information	- Clinical notes Facts	✗	Clinical notes • Facts • Treatments videos • Condition videos • Exercise Videos • Streches Videos	✓
Human Femoral Fractures Info	✗	✗	✗	✓
Offline Available	✓	✓	✓	✓
Cost	Free	Free	Costly	Free

2.4 Femur Fracture

2.4.1 Study of Human Femur Fracture

Femoral shaft fractures exhibit a diverse array of patterns, each offering unique insights into the nature and magnitude of the forces that lead to such injuries.

One of the most common femoral shaft fractures is Transverse fractures, characterized by a straight horizontal break, typically result from direct forces applied perpendicular to the femur's longitudinal axis.

On the other hand, oblique fractures showcase an angled line along the shaft, indicating the influence of angular forces during the traumatic event.

The distinctive candy cane-like appearance of spiral fractures signifies a rotational or twisting force impacting the thigh.

Comminuted fractures, with the bone fragmenting into multiple pieces, often signify high-energy trauma, emphasizing the severity of the applied force.

After that, Linear fractures in the femoral shaft occur when there is a straight, horizontal break across the bone. The line of the fracture runs perpendicular to the long axis of the femur. These fractures can result from a direct impact or force applied to the femur.

Besides, Greenstick fractures are incomplete fractures, common in pediatric populations where bones are more flexible. In a greenstick femur fracture, the bone is bent, causing a crack on one side while the other side remains intact. This type of fracture resembles the way a green twig breaks, hence the name.

Among these, open or compound fractures present a particularly intricate scenario, where a bone fragment breaches the skin or a wound extends to the fractured site. Such fractures involve heightened complexity, as the risk of complications, especially infections, is elevated, demanding thorough clinical attention. Recognizing and understanding the nuances of these femoral shaft fractures is essential for orthopedic practitioners to tailor effective treatment plans, ensure optimal patient outcomes, and advance the field's knowledge in fracture biomechanics.

2.4.2 Fatality Rate of Femur Fracture

Femur fractures, particularly in the elderly population, pose a significant risk to overall health and survival. The 1-year case fatality rate for patients with femur fractures has been reported to be alarmingly high, ranging from 20% to 24% [16] This elevated mortality rate underscores the severe impact of femur fractures, often exacerbated by underlying health conditions and complications arising from the injury. Factors contributing to this high case fatality rate include the increased risk of postoperative complications, such as infections and cardiovascular events, as well as the challenges in mobilizing and rehabilitating patients who are often frail and have other comorbidities. These statistics highlight the urgent need for improved management strategies and preventative measures to enhance patient outcomes and reduce the mortality associated with femur fractures.

CHAPTER 3

Proposed Method/Approach

3.0 Objective and Vision

The primary goal of this project is to develop an Augmented Reality (AR) application focused on the human femur and its fractures. The app will provide an immersive, interactive educational experience for medical students and educators, allowing them to explore femur anatomy, interact with 3D models, and compare different fracture types. It will be accessible on mobile devices, ensuring broad usability and convenience.

3.0.1 Key Features

- **Interactive 3D Models:** High-resolution 3D models of the human femur, allowing users to rotate, zoom, and isolate specific parts for detailed study.
- **Educational Annotations:** Detailed descriptions and annotations on different parts of the femur, providing in-depth information on anatomy, common injuries, and treatments.
- **Comparison of multiple femur Fractures:** Ability to spawn multiple femur fractures side by side, helping users understand the differences and implications of each fracture type.

3.0.2 Development Strategy

Platform Selection:

- The application will be developed using Unity, which supports cross-platform development, allowing for deployment on both Android and iOS devices.
- Unity AR Foundation will be used to implement AR functionalities, ensuring compatibility with a wide range of devices.

Modeling and Texturing:

  - High-fidelity 3D models of the femur will be created using Blender or similar 3D modeling software.
  - Texturing and material creation will ensure realistic representation, with attention to anatomical accuracy.

- **AR Integration:**
  - Implement AR features using Unity AR Foundation, allowing users to place the femur model in their physical environment.
  - Ensure smooth tracking and interaction within the AR environment, using marker-based or world-based tracking depending on the device's capabilities.

By following this approach, the femur AR application will not only serve as a powerful educational tool but also push the boundaries of how medical anatomy can be taught and understood through technology.

3.0.3 Methodology

Before beginning the system development, selecting an appropriate methodology is crucial, especially for a project being built. For this project, the prototype model was chosen as the development methodology. The prototype model is ideal in situations where initial specifications are unclear, as it allows for the creation of a preliminary prototype with minimal requirements. This prototype is then iteratively tested and refined based on user feedback, ensuring that the final system meets all user requirements.

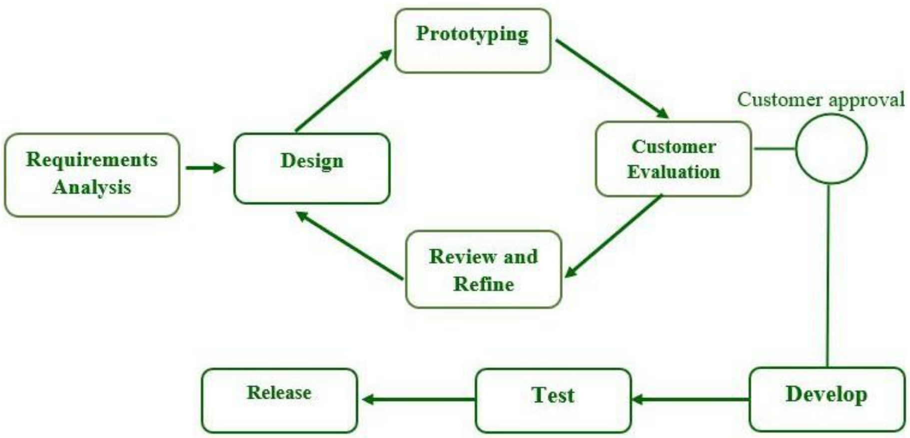


Figure 3.1-1 Methodology of Proposed System

Stage 1: Requirements Gathering and Analysis

The first step in the project involves identifying user requirements. This is done by interviewing users or project stakeholders to understand their expectations from the system. Understanding these requirements helps define the project scope. Additionally, a feasibility study is conducted to assess the project's technical aspects, estimated costs, and potential benefits. If the project is deemed feasible, it moves on to the next stage.

Stage 2: Design, Prototyping and Evaluation (quick design)

In the second stage, the processes of design, prototyping, and evaluation are closely interwoven. An initial design is created early in this stage, leading to the development of a prototype. This prototype allows project stakeholders to interact with a realistic version of the software, ensuring that the requirements are being met and providing a basis for evaluation. Often, users will suggest additional requirements or modifications, prompting the development of a new prototype. This cycle of design, prototyping, and evaluation continues until the users are satisfied with the system.

Stage 3: Implementation and Maintenance

Once the final system has been fully tested by both developers and project stakeholders to ensure it meets all requirements and performs without errors, it is ready for implementation. Following deployment, a maintenance phase may be conducted to address any issues that arise with the developed system.

3.1 System Requirement

3.1.1 Hardware

The hardware involved in this project is computer and android mobile device. A computer issued for the process of 3D visualization and segmentation from MRI and CT datasets to obtain the 3D model objects, then it also used for applying AR technology on the 3D model objects. A mobile device is used for testing and deploying this AR application in learning human anatomy

Table 3.1 Specifications of laptop

Description	Specifications
Processor	Intel Core i3-12300
Operating System	Windows 11
Graphic	AMD Radeon RX 5600XT
Memory	16GB DDR4 RAM
Storage	1TB SATA SSD

3.2.1 Technologies Involved

Table 3.2.2 Tools and Software

Tools / Software	Description
Unity	Unity is a cross-platform game engine that is currently commonly used in developing video games. It supports both the 2D and 3D environments for PC and mobile development. The native programming language used in Unity is C#. It will be used as the main development tool for developing the 3D educational mobile application for femoral shaft fractures.

Visual Studio 2022	Visual Studio 2022 is an IDE mainly for the purpose of coding, and there are several languages supported in it, such as C#, C++, Python, Node.js, and others. It also can be used to develop mobile apps, websites, web apps, web services, and computer programs. It will be used for coding the scripts for making the mobile application function well.
Blender	Blender is a free and open-source software for 3D environments, such as modelling, rigging, animation, rendering, compositing, motion tracking, as well as video editing. It will be utilised for modelling the types of fracture bones.
C# programming language	C# is natively supported by Unity, and with Visual Studio 2022, some user-interaction features of the mobile application will be programmed in C#.
Firebase	Firebase is a NoSQL cloud-hosted database that is used to store, sync, and query app data on a large scale. It will be used to sync data from PlayerPrefs and store it in the cloud to prevent data loss in the event that the application is removed or reinstalled.

Unity AR Foundation	AR Foundation is a package that lets you build cross-platform AR applications inUnity3D.you can develop your AR application in Unity3D andthen build it either for Android or iOS.Vast community support,easy access to Unity3D codebase & asset store It will be used for simulating AR Enviroment

3.3 User Requirements

3.3.1 Functional Requirements

3D Model Interaction

- Users can spawn and manipulate 3D models in AR space
- Multi-touch gesture support for model manipulation:
  - Double-tap to place or relocate objects
  - Touch and drag for rotation
  - Two-finger pinch for scaling
  - Long-press (0.7 seconds) for object deletion
- Support for multiple object variants (e.g., femur models)
- Maximum of 2 objects can be displayed simultaneously
- Objects automatically orient towards the camera for optimal viewing
- Toggle movement mode for precise object positioning

Object Management

- System maintains object spawn order queue
- Automatic removal of oldest object when limit is reached
- Object position persistence during session
- Support for cycling between different prefab models
- Collision detection and physics interactions
- Automatic scaling based on predefined factors

AR Environment Integration

- Plane detection for object placement

- Raycast-based object positioning
- Height offset adjustment for floating objects
- Support for AR Foundation framework
- Material and renderer management

3.3.2 Non-Functional Requirements

Performance

- Touch response time under 100ms
- Smooth gesture recognition
- Efficient object spawning and destruction
- Enhanced touch support for precise interactions
- Movement threshold of 10 pixels for drag detection

Reliability

- Error handling for missing components
- Consistent object state management
- Logging system for debugging and monitoring

Usability

- Intuitive touch gesture controls
- Clear visual feedback for user actions
- Consistent UI button placement
- Predictable object behavior
- Short learning curve for basic interactions
- Clear distinction between interaction modes

CHAPTER 4

System Design

4.1 System Flow Chart

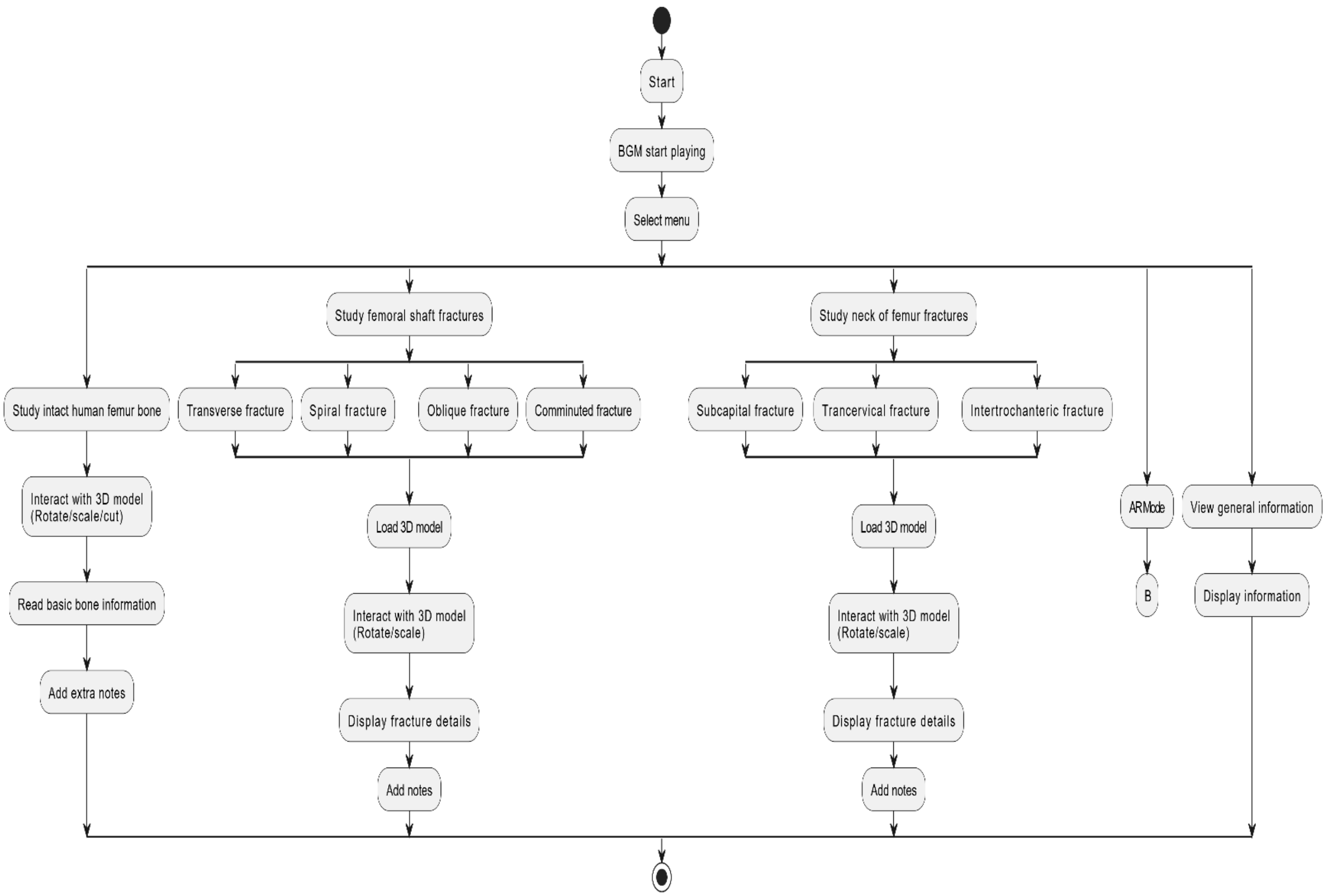


Figure 4.1-1 Main Flow Chart

The main application flowchart illustrates the core navigation and learning features of the femur study app. Upon starting the application, users are greeted with background music and a menu offering several parallel options: studying an intact human femur bone, exploring different types of femoral shaft fractures, or viewing general information. If the user chooses to study an intact femur, they can interact with a 3D model, access basic information, and add notes. Selecting femoral shaft fractures leads to a choice among four fracture types, each converging at a single point before allowing the user to interact with a 3D model of the selected fracture, review detailed information, and add notes. Viewing general information simply displays the relevant content. All user paths eventually merge at a common endpoint, ensuring a consistent and unified user experience.

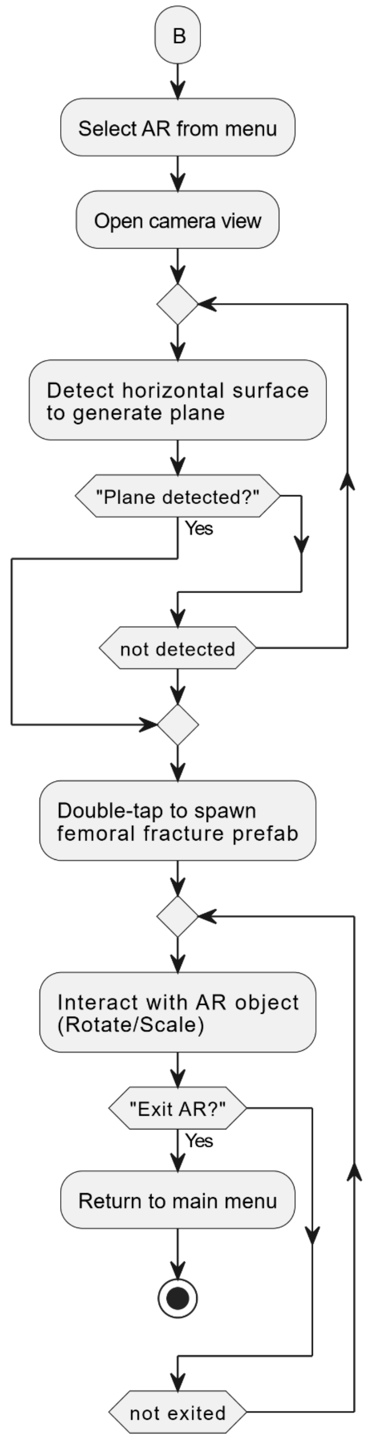


Figure 4.1-2 AR Feature Flow Chart

The AR feature flowchart details the process when a user selects the augmented reality option from the menu. The application opens the camera and continuously scans for a horizontal surface to establish an AR plane. Once a suitable plane is detected, the user can double-tap to spawn a femoral fracture model into the real-world environment. The user is then able to interact with this AR object—rotating, scaling, or cutting it—using the available controls. This interaction loop continues until the user decides to exit the AR mode, at which point they are returned to the main menu. This flow ensures a smooth and immersive AR experience, seamlessly integrated with the app's overall structure.

4.2 System Architecture Diagram

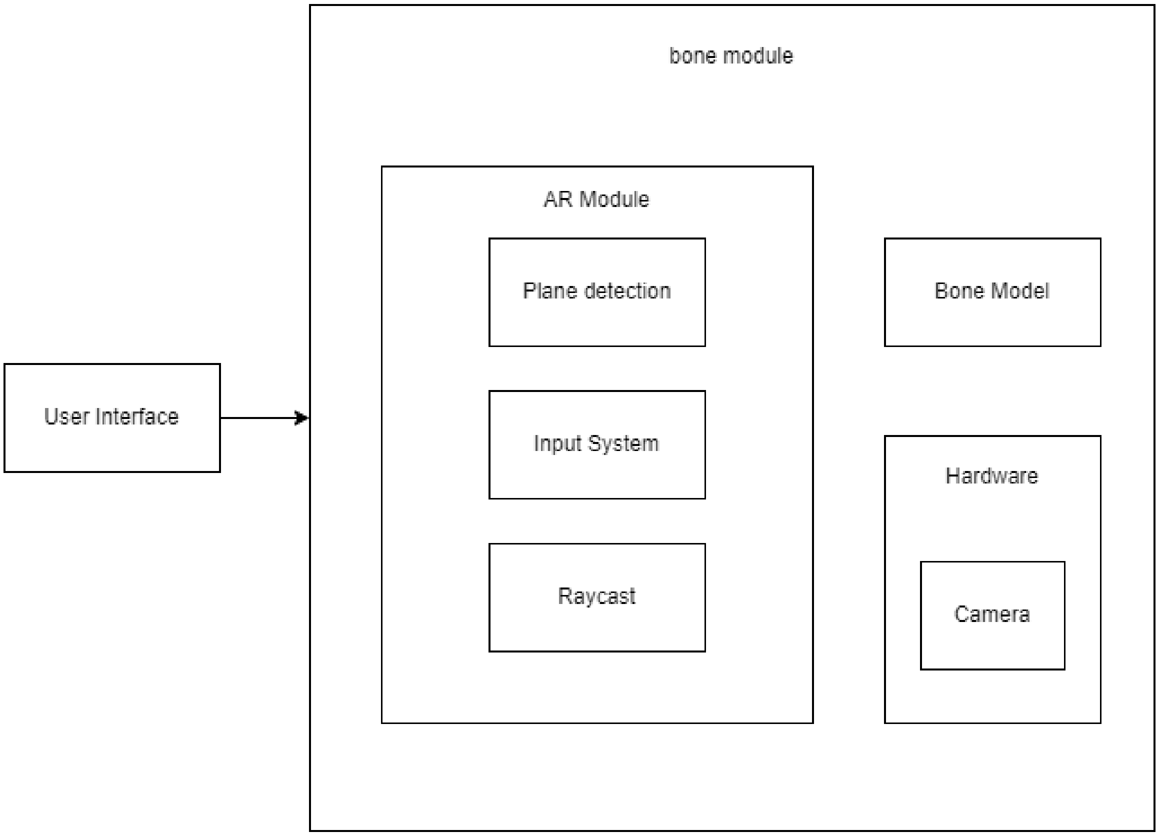


Figure 4.2-1 System Architecture Diagram

User Interface

This is the front-facing component where users interact with the AR application. It includes all the visual and interactive elements that the user sees and uses, such as buttons, menus, and the display of the AR environment.

Bone Module

This is the core module of the system, focusing on the AR interaction with a bone model. It includes various subcomponents:

AR Module

The AR Module is a critical part of the system that handles all the augmented reality functionalities. It is broken down into three subcomponents:

Plane Detection: Responsible for detecting flat surfaces in the real world where the AR content, such as the bone model, can be placed. This component uses the device's sensors and camera to identify and track planes.

Input System: Manages user inputs like taps, gestures, and other interactions within the AR environment. It ensures that the application responds correctly to user actions.

Raycast: This subcomponent is used to calculate and determine where a user's touch or gesture intersects with the virtual objects in the AR space. It helps in placing, moving, or interacting with the bone model based on user input.

Bone Model

This represents the 3D model of the bone that is being interacted with in the AR environment. The bone model is likely the primary object that users will examine, manipulate, or study.

Hardware

The hardware component refers to the physical devices involved in running the AR application. It includes:

Camera: The device's camera is essential for capturing the real-world environment and overlaying the virtual bone model onto it. The camera feeds the necessary data for plane detection, raycasting, and overall AR functionality.

4.3 Activity Diagram

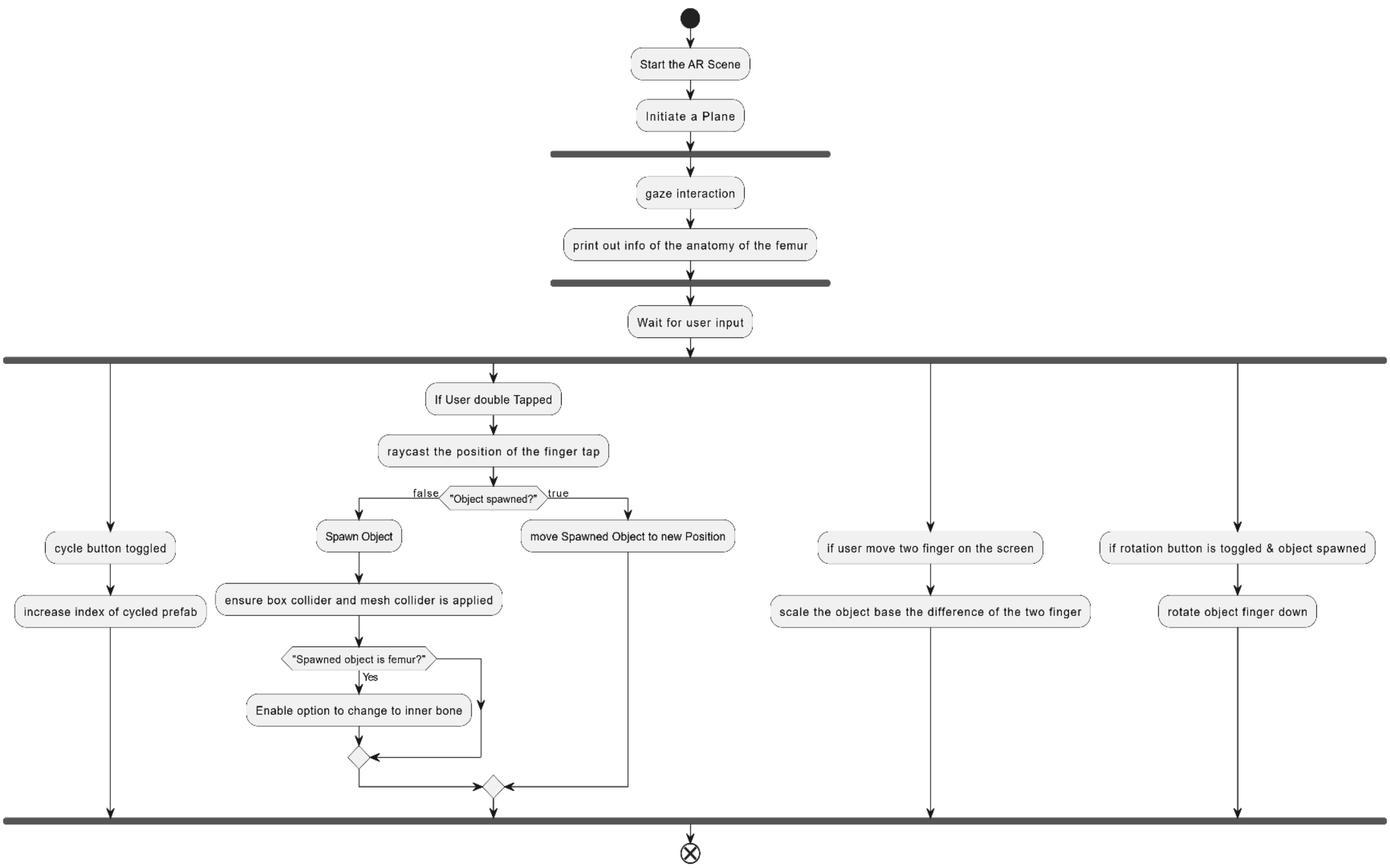


Figure 4.3-1 Activity Diagram

Start the AR Scene:
The AR application initializes, setting up the AR environment and preparing all necessary components for user interaction.

Initiate a Plane:
The system scans the real world using the device's camera to detect a flat surface (plane). This plane will serve as the foundation for placing virtual objects.

Gaze Interaction:
While the AR environment is active, the app monitors where the user is looking (gaze interaction).

- If the user gazes at a specific part of the femur, the application prints out detailed anatomical information about that part, enhancing the educational experience.

Wait for User Input:
After the plane is established and gaze interaction is available, the app waits for further input from the user to perform various actions.

User Input Actions (All in Parallel):
The following actions can happen independently and simultaneously:

- Cycle Button Toggled:
  If the user presses the cycle button, the app increases the index of the currently selected prefab, allowing the user to browse different models that can be spawned.

- User Double Tapped:
  When the user double-taps the screen, the app raycasts to determine the exact tap position on the plane.

  - If no object is present at that location, the app spawns a new object there and ensures it has proper physical properties (box collider and mesh collider).

  - If an object already exists, the app moves the spawned object to the new tapped position.

  - If the spawned object is a femur, the app enables an option for the user to change it to an inner bone model.

- If User Moves Two Fingers on the Screen:
  The app detects pinch or spread gestures, and scales the object based on the distance between the two fingers, allowing dynamic resizing.

- If Rotation Button is Toggled & Object Spawned:
  If the rotation button is toggled and an object is present, the app allows the user to rotate the object by moving a finger in a circular motion.

- If Gaze Looked at an Object:
  Whenever the user's gaze focuses on an object, the app displays information about that specific part, supporting interactive learning.

CHAPTER 5

System Implementation

Preliminary Research is research on a topic that helps you get a better understanding on what types of sources are available and what is being said about a topic. This type of research helps solidify a topic by broadening or narrowing it down. This research can also help you when choosing Search Terms.

5.1 Software Setup

5.1.1 Unity Installation

Step 1: Download Unity from https://unity.com/download#how-get-started

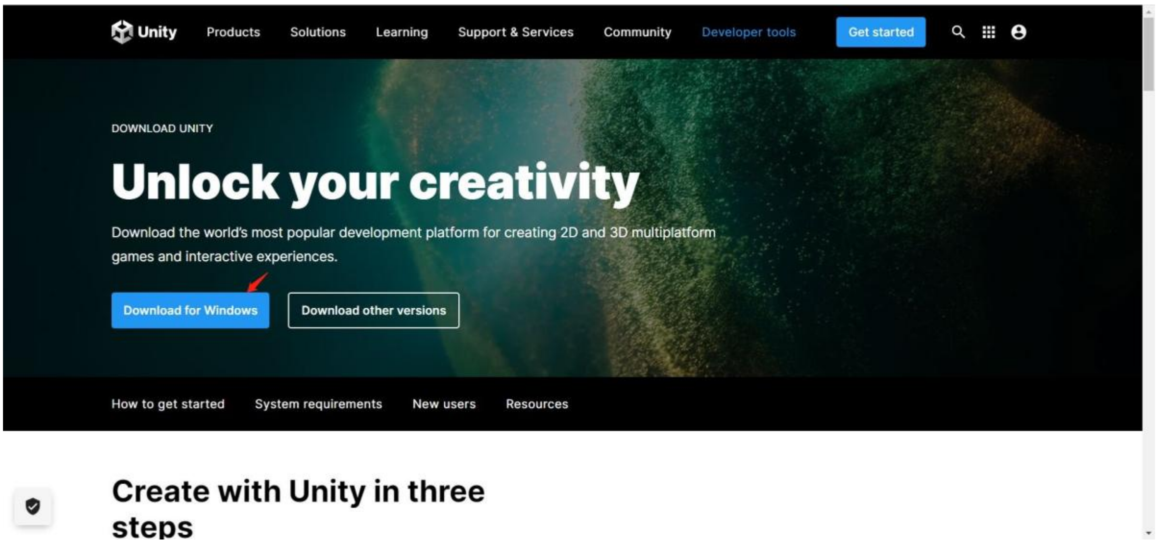


Figure 5.1.1-1: Download UnityHub

Step 2: Agree with License and Install UnityHub

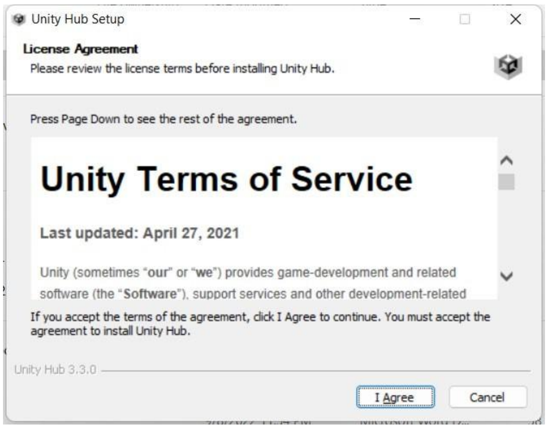


Figure 5.1.1-2: Agree with the License

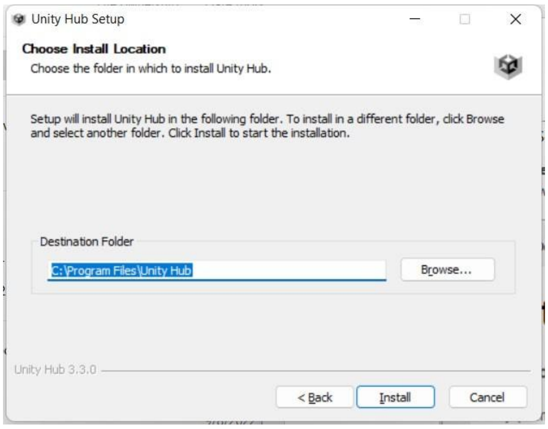


Figure 5.1.1-3: Install UnityHub

Step 3: Open UnityHub and Install Editor

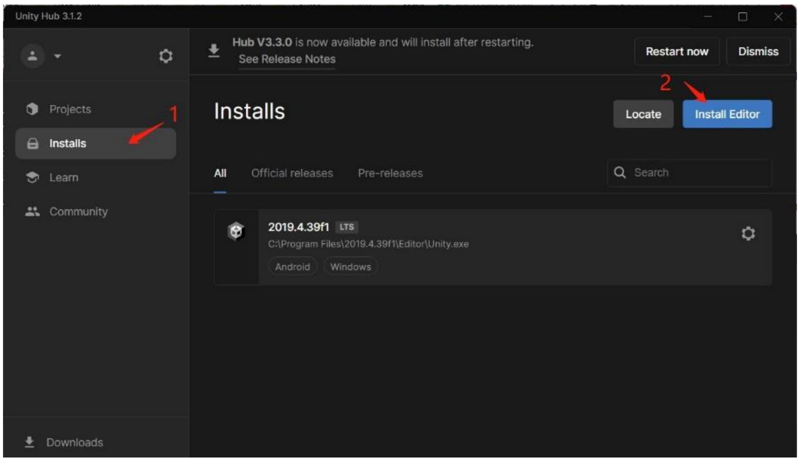


Figure 5.1.1-4: Select Editor Version to be Installed

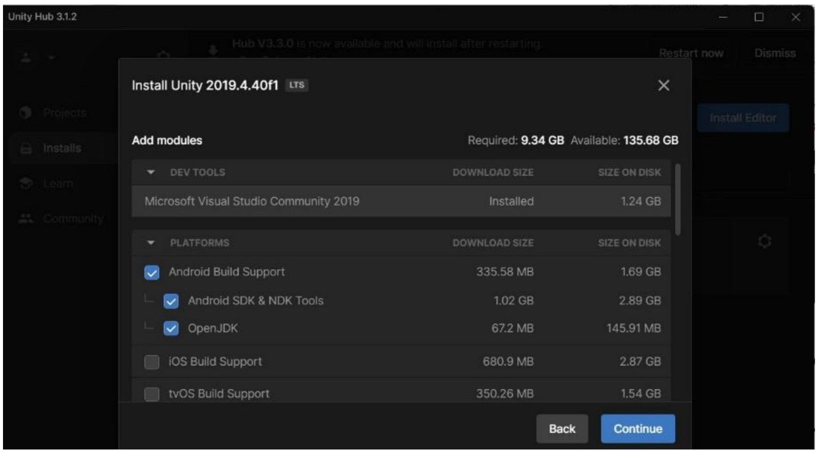


Figure 5.1.1-5: Select Module to be Installer

Step 4: License Activation

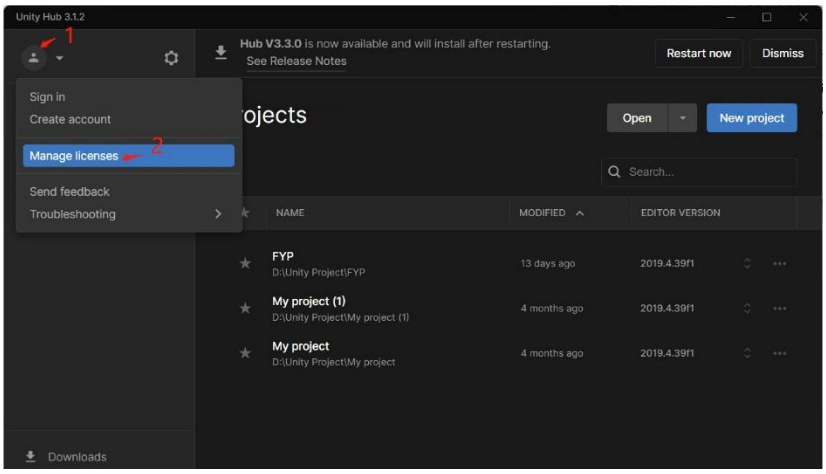


Figure 5.1.1-6: Select Manage Licenses

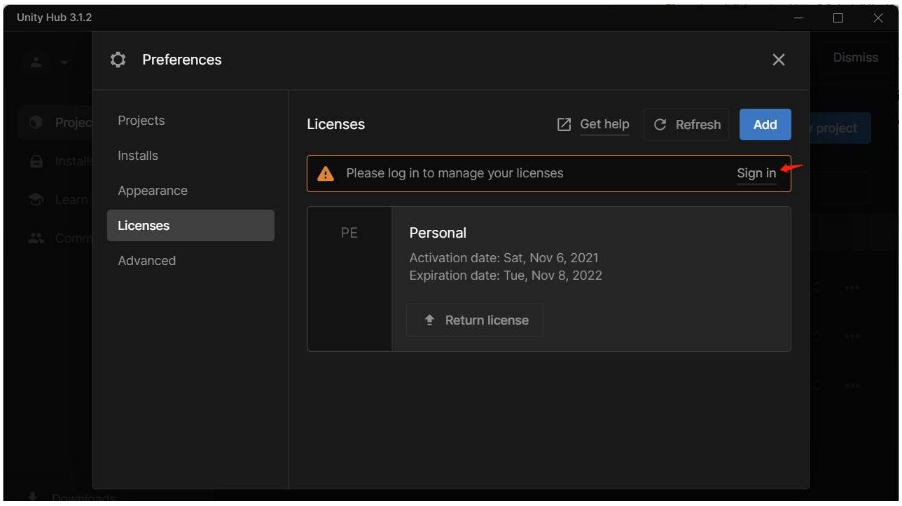


Figure 5.1.1-7: Sign In

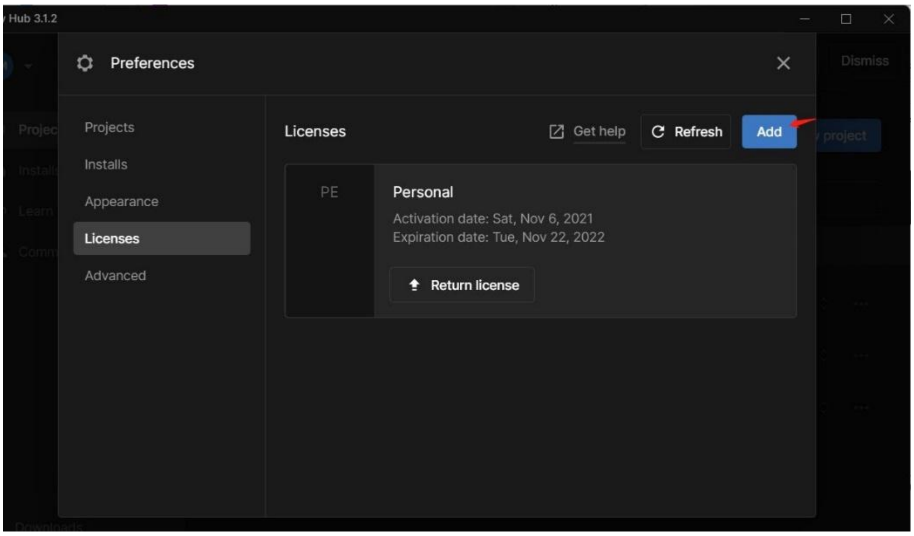


Figure 5.1.1-8: Add New License

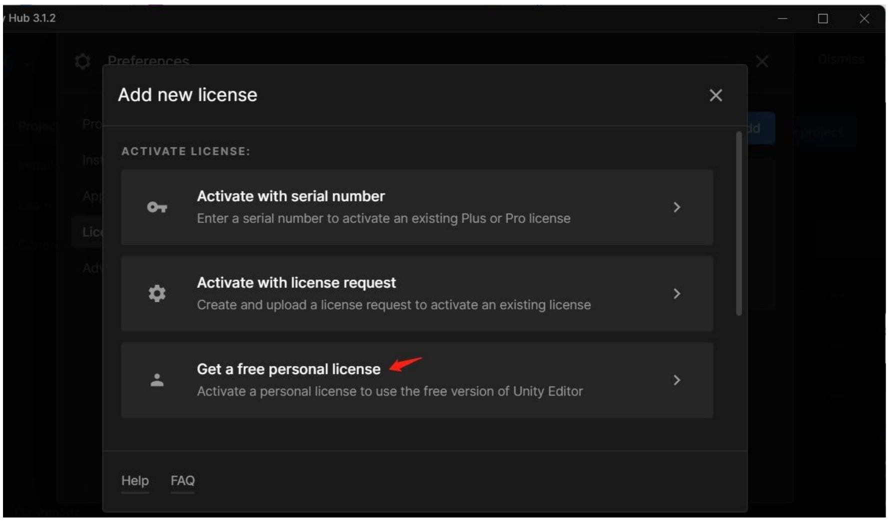


Figure 5.1.1-9: Activate Free Personal License

5.1.2 Visual Studio 2022 Installation

Step 1: Download Visual Studio Community 2022 from https://visualstudio.microsoft.com/vs/

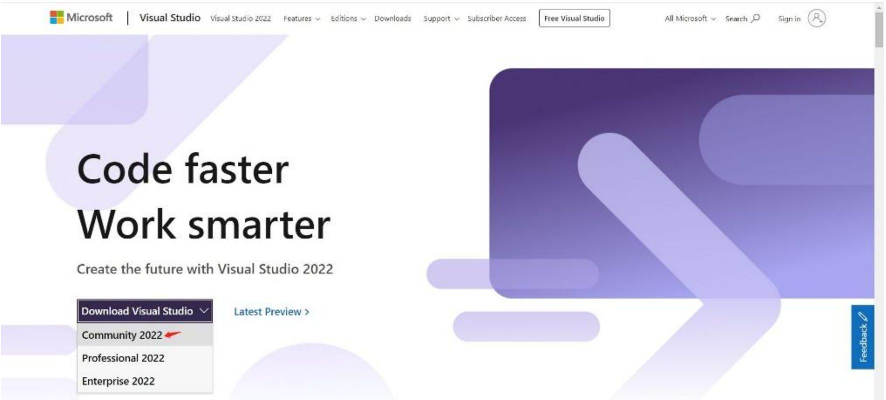


Figure 5.1.2-1: Download Visual Studio Community 2022

Step 2: Install Visual Studio Installer

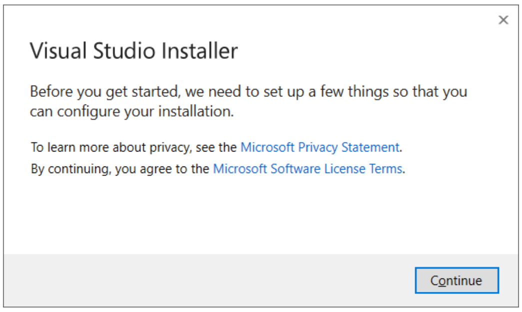


Figure 5.1.2-2: Select Continue and Agree with the License Terms

Step 3: Select and Install Workloads

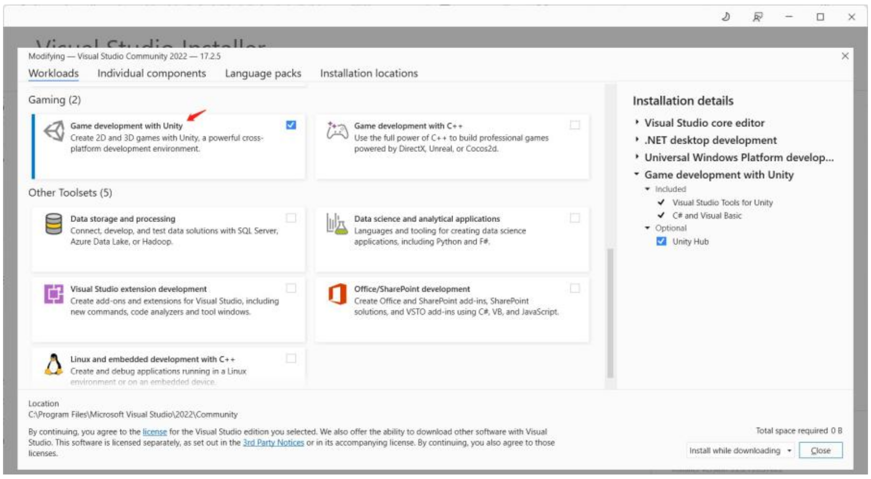


Figure 5.1.2-3: Choose the Workloads to be Installed

5.1.3 Blender Installation

Step 1: Download Blender from https://www.blender.org/download/

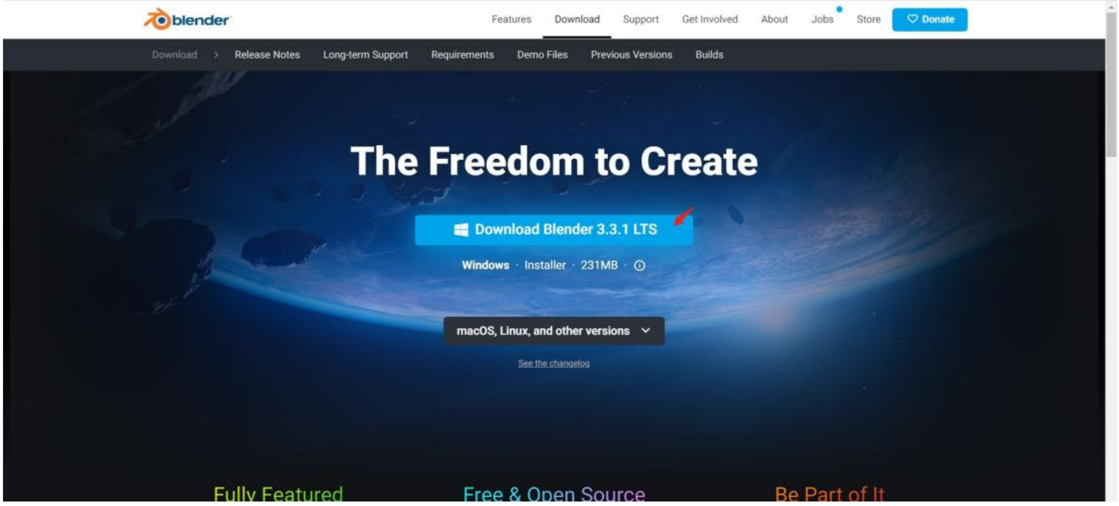


Figure 5.1.3-1 Download Blender

Step 2: Install Blender

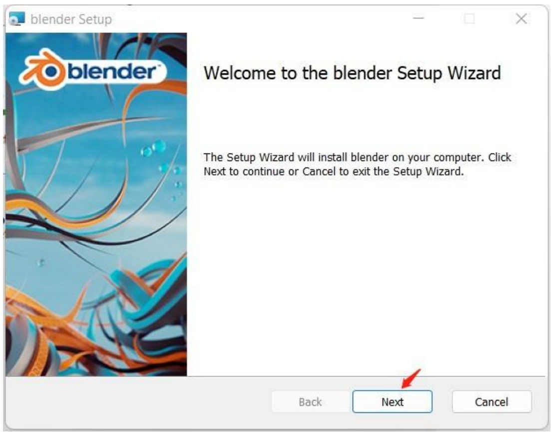


Figure 5.1.3-2 Click "Next"

Figure 5.1.3-3 Agree with the License Term

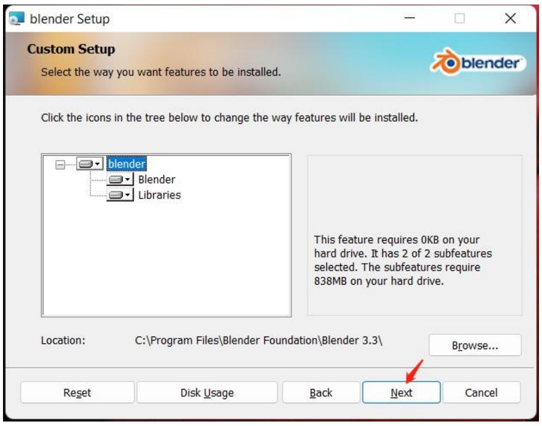


Figure 5.1.3-4 Browse Location for Installation

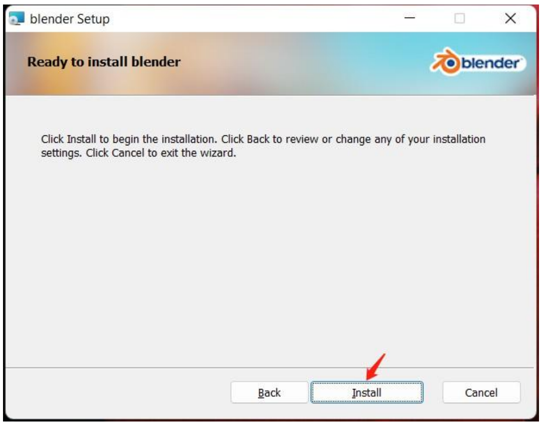


Figure 5.1.3-5 Install Blender Blender Installation

5.2 Setting and Configuration

5.2.1. Linkage between Software

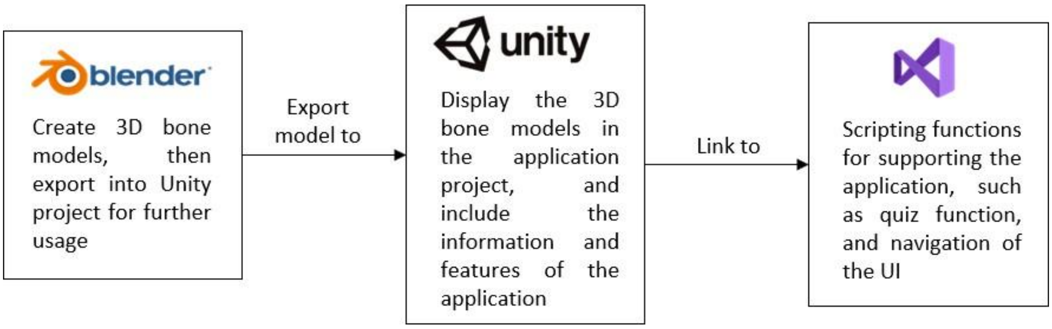


Figure 5.2.1-1 Relationship among the Software

After installing the software needed (Unity, Visual Studio 2022, Blender), Visual Studio 2022 is required to be linked with Unity for scripting the functions of the application, while Blender is used to create 3D bone model. The steps for linking the Unity and Visual Studio 2022 are as follow:

Open Unity Editor

Go to Edit > Preferences > External Tools

Set the External Script Editor as Visual Studio Community 2022

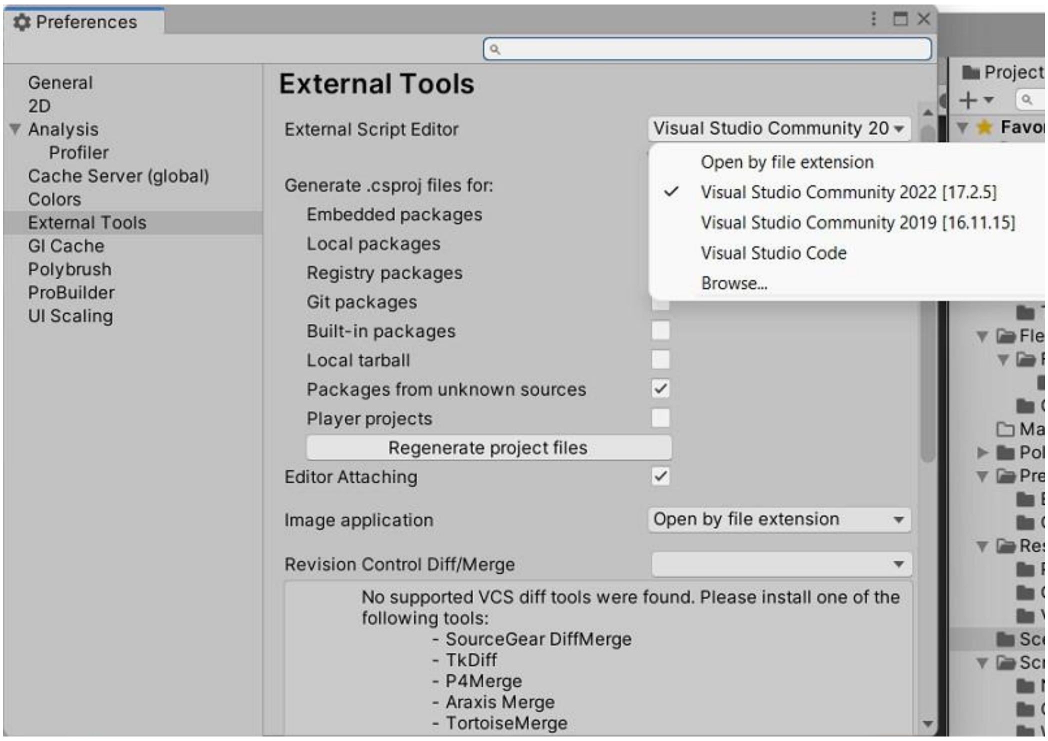


Figure 5.2.1-2 Linkage between Visual Studio and Unity

Before developing the application, 3D models of the bones should be prepared, where Blender had been chosen for creating the models in this project. After the models are created, the models are exported to the Unity project as .fbx file. The steps of exporting the models are as follow:

In Blender, go to File > Export > FBX

Select Unity project folder (In my case, I created and saved the models in a folder named “bones” in the “prefabs” folder of the Unity project. To only export the models, I ticked the checkbox of “Selected Objects” during exporting.)

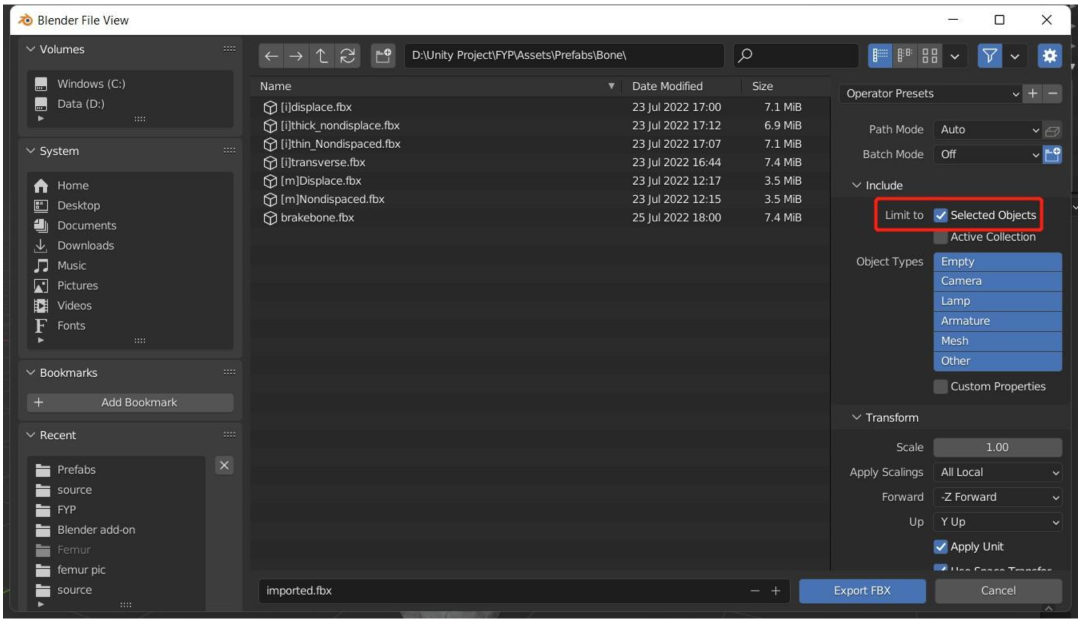


Figure 5.2.1-3 Export models from Blender to Unity

5.2.2. Device Simulator Setup

Besides, since this project is going to be developed on mobile platform, a device simulator is needed to test if the application is work in different mobile devices. The steps to install the device simulator in Unity are as follow:

Go to Window > Package Manager

Choose “Unity Registry”

Look for “Device Simulator”

Go to “Advanced > “Show preview packages” (if “Device Simulator” not found)

Install it, then the simulator option should appear in “Game”

(In my case, I already installed, hence, it shows “up to date” rather than “install”)

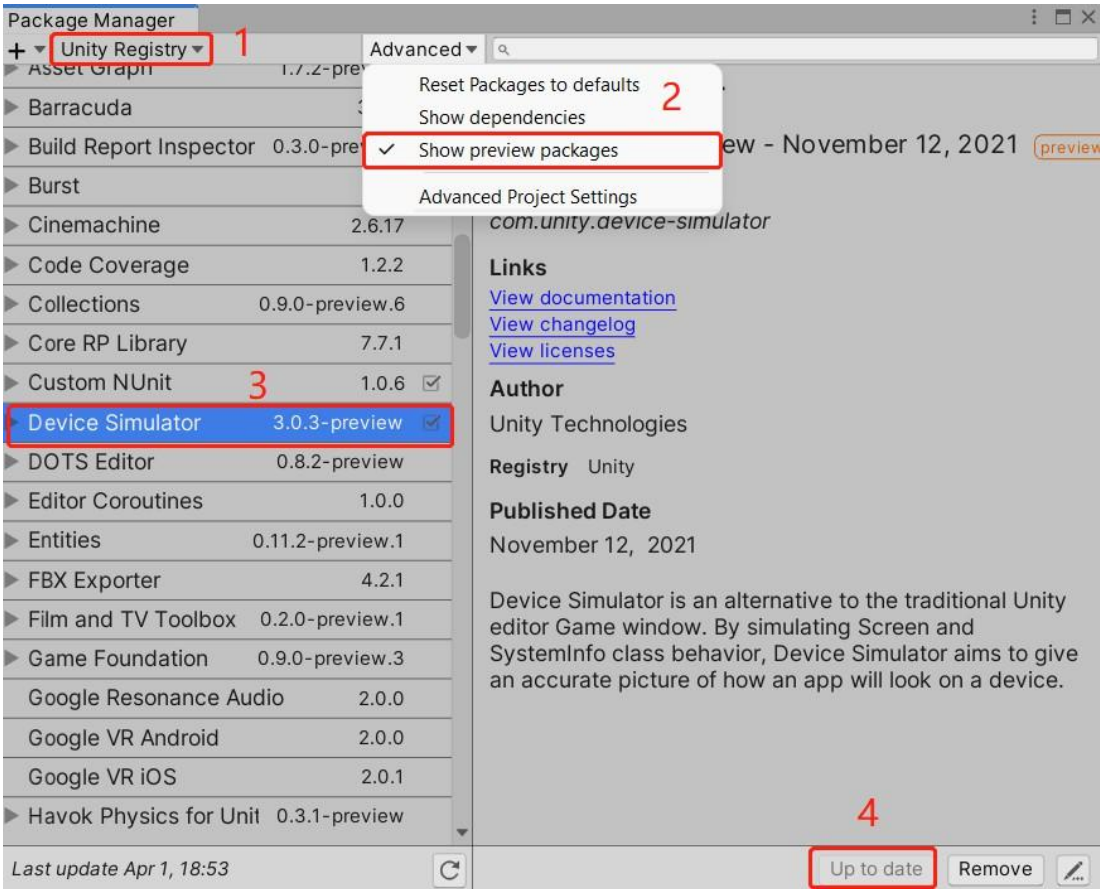


Figure 5.2.2-1 Installation of Device Simulator

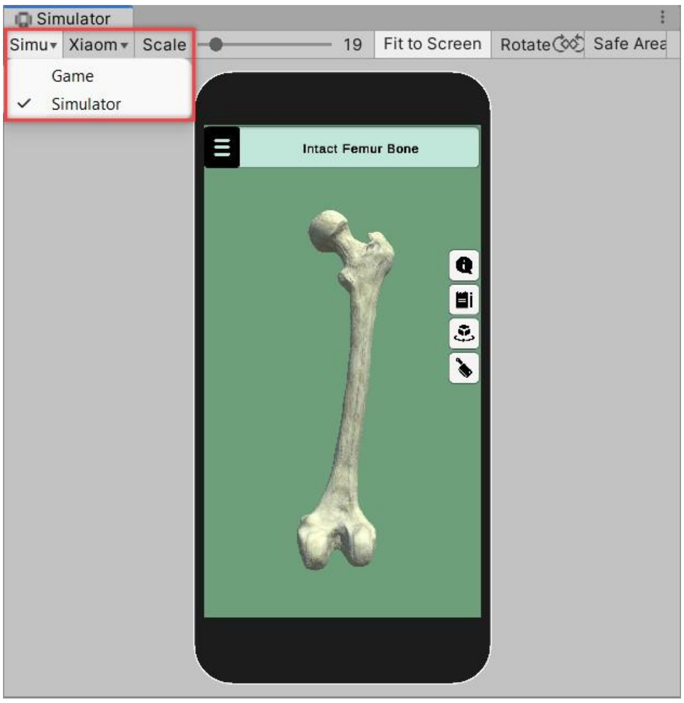


Figure 5.2.2-2 Simulator Option Appeared

5.2.3. AR Foundation Setup

Since this is an AR project, we will need an AR SDK to develop the application. The following steps guide you through setting up AR Foundation in Unity:

Go to Window > Package Manager.

In the Package Manager, search for and install the following packages:

- **AR Foundation**
- **ARCore XR Plugin** (for Android)

Go to File > Build Settings.

For Android, make sure to set the Minimum API Level to 7.0 (API Level 24) or higher.

Then, under Project Settings

Ensure that ARCore Supported is enabled under XR Plug-in Management.

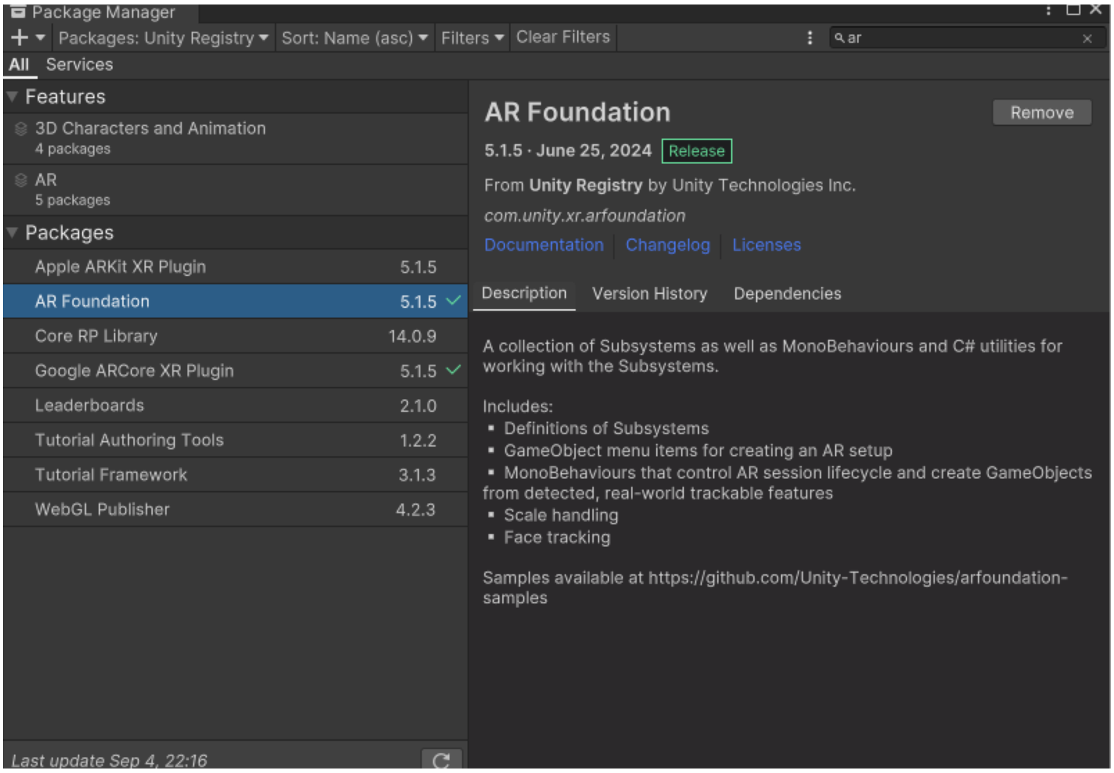


Figure 5.2.3-1 AR Foundation Successfully installed

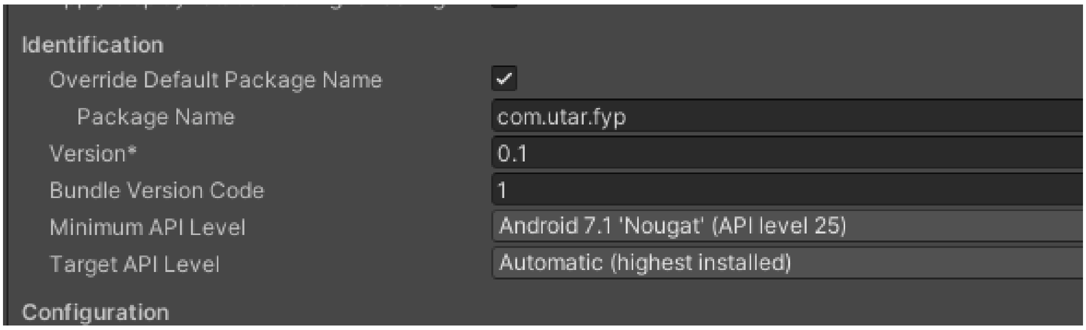


Figure 5.2.3-2 Minimum Android Api Set at 7.1

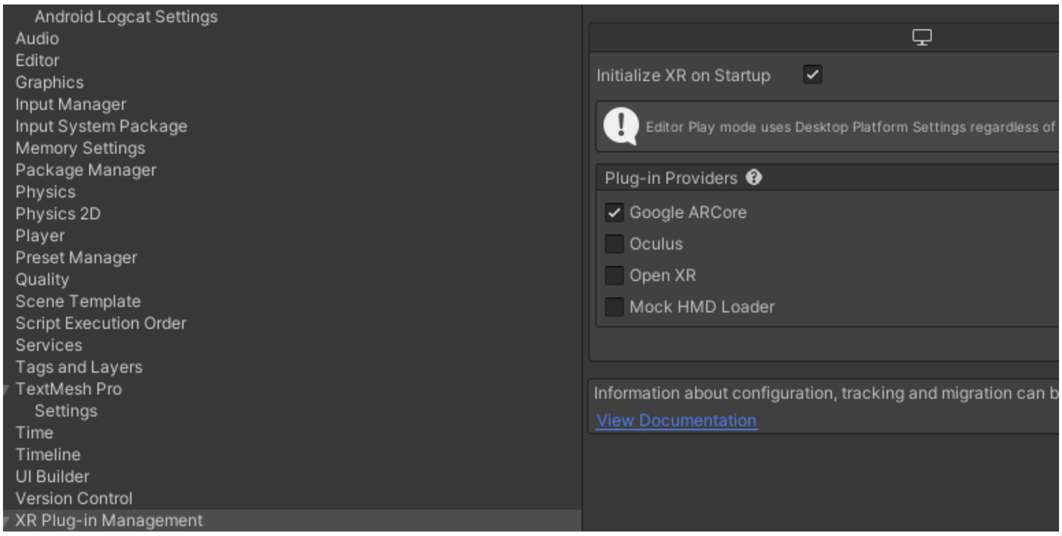


Figure 5.2.3-3 ARCore enabled in XR Plug-in

5.3. System Operation

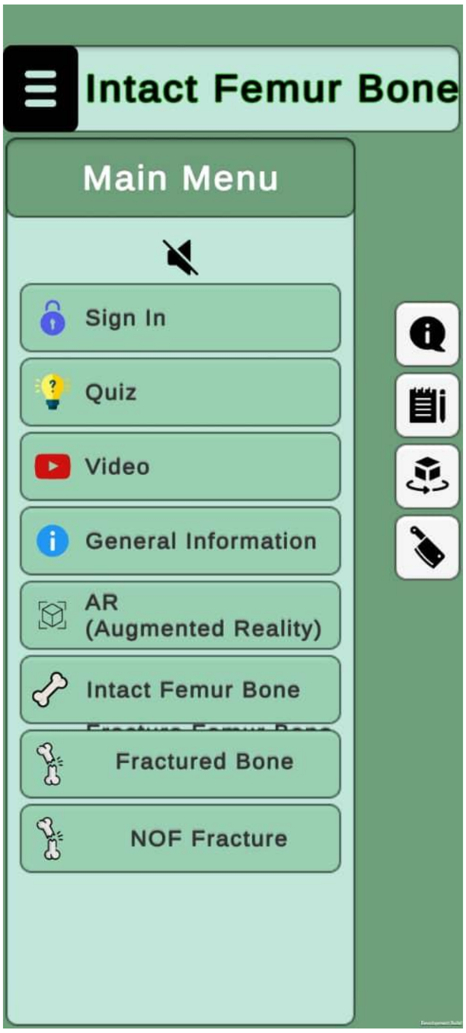


Figure 5.3-1 Menu Selection

Access the Menu: Open the application or software where you need to select Augmented Reality.

Navigate to the AR Option: Look for a section or menu related to Augmented Reality. This might be labeled as "AR," "Augmented Reality," or something similar.

Select Augmented Reality: Click or tap on the Augmented Reality option to activate or configure AR features.

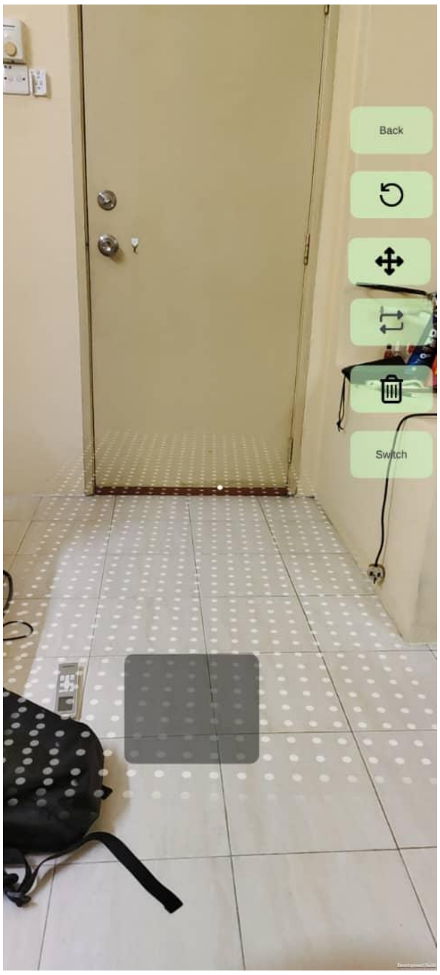


Figure 5.3-2 Plane Detected

Initiate Plane Detection: Start the plane detection process within your AR application.

Wait for Detection: Allow the system to scan the environment. The application will analyze the camera feed to identify horizontal surfaces.

Detection Confirmation: Once the system successfully detects a plane, it will be highlighted or visualized on the screen.

Plane Visualization: A visual representation of the detected plane will appear, indicating the detected surface where AR objects can be placed.

Figure 5.3-3 Object Spawned

Double-Tap to Spawn: Double-tap on the detected plane using your device's screen.

Object Appearance: Upon double-tapping, an AR object will be spawned and positioned on the plane where you tapped.

Figure 5.3-4 Object Scaled

Scale Using Two Finger: the object can be scaled by pinching to shrink or spreading to enlarge it.

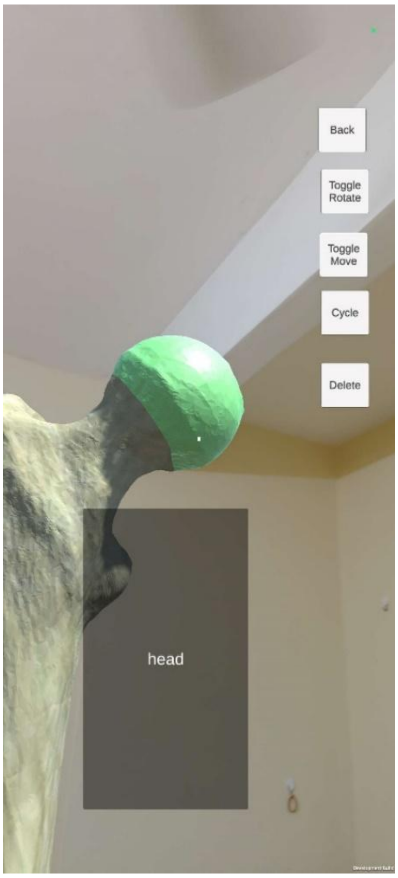


Figure 5.3-5 Object information displayed

Information Overlay: When the gaze is detected on the object, relevant information about the object will be displayed.

View Details: The information overlay will provide details such as the object's name, description, or other pertinent data.

Maintain Gaze: Keep gazing at the object to keep the information displayed. The overlay will disappear once you move your gaze away.

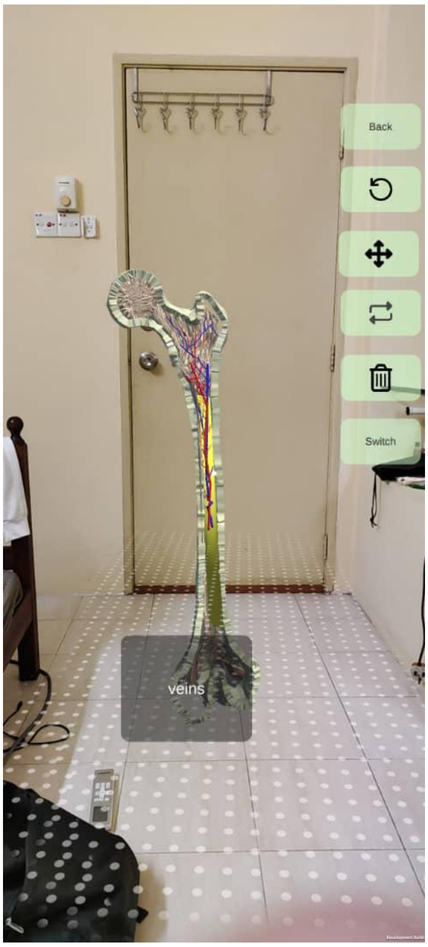


Figure 5.3-6 Change to Inner Bone

Change to Inner Femur Anatomy: Tap on the Switch Button which will change the Femur To Inner Femur Anatomy.

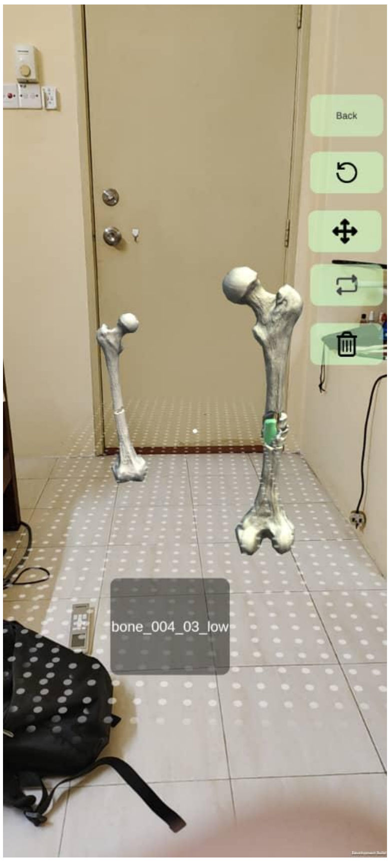


Figure 5.3-7 Comparison of Fractures

Cycle though Bones: Tap on the cycle Button to change the type of bone to be spawn

Spawn the First Bone: Tap on the screen to place the first fractured bone in the AR environment.

Repeat for Additional Bones: Tap again on different locations in the AR space to spawn additional fractured bones. Each bone can be of a different type or the same type for comparison.

Arrange for Comparison: Move and arrange the spawned fractured bones to view and compare them easily. Use any provided tools or features in the AR app to position the bones as needed

Figure 5.3-8 Back To Main Menu

Going Back to the Menu: Press Back On the side of button, which will bring user back to the main menu

Figure 5.3-9 NOF Fracture List

Showing the List of NOF fractures: Press on the NOF Fracture button and a list of different type of NOF fracture will be shown.

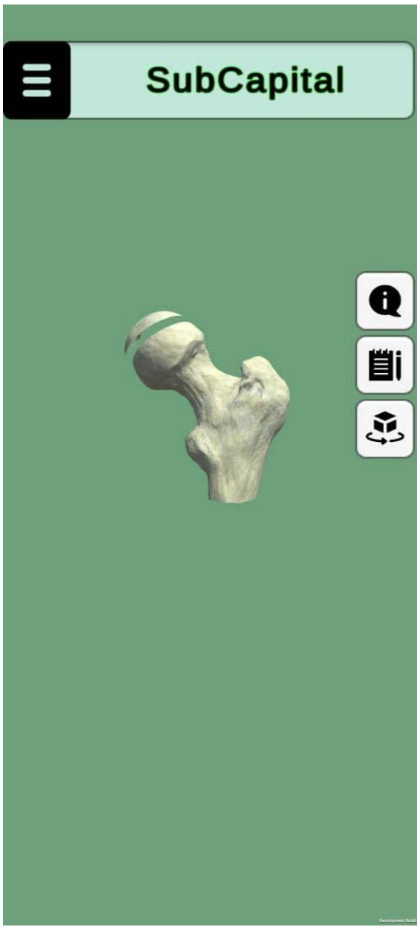


Figure 5.3-10 NOF Fracture Shown

Showing the NOF fracture: Press on button in the NOF fracture list and the type of NOF Fracture is shown for user

CHAPTER 6

System Testing and Evaluation

6.1. System Testing

To ensure the reliability and robustness of the AR features developed in this project, comprehensive system testing is essential prior to release. The primary testing approach selected for these AR functionalities is a combination of user case testing and black-box testing. This strategy is designed to thoroughly evaluate the AR system from the perspective of end users, ensuring that all functional requirements are met in real-world scenarios.

User case testing involves designing and executing test cases that reflect typical user interactions with the AR application. These scenarios include actions such as spawning AR objects, cycling through different prefabs, interacting with UI panels, and utilizing dropdown menus. By simulating real user behavior, user case testing helps verify that the system responds appropriately and intuitively to all expected actions, providing a seamless and satisfying user experience.

Black-box testing is employed to validate the AR system without any knowledge of the underlying code or implementation details. Testers provide various inputs through the AR interface—such as tapping on the screen to place objects, pressing buttons to cycle prefabs, or selecting options from dropdown lists—and observe whether the outputs and behaviors align with the expected results. For example, testers check that AR objects appear at the correct scale and position, that UI panels display and fade as intended, and that error messages are shown when necessary. This approach is invaluable for ensuring that the system meets its functional requirements and behaves correctly from the user's perspective.

By combining user case testing and black-box testing, the AR features are rigorously evaluated in a manner that closely mirrors actual usage. This approach increases confidence that the application will perform reliably and intuitively for end users. Any issues discovered during these tests can be addressed early, leading to a more stable and user-friendly AR experience upon release.

6.2. Testing Setup and Result

6.2.1. Testing Setup

1. Enable Developer Mode on the Phone (if not already enabled)

- Go to Settings > About Phone > Tap "Build Number" 7 times until developer mode is activated.
- If already enabled, you can skip this step.

2. Enable USB Debugging

- On your phone, go to: Settings > System > Developer Options > Enable "USB Debugging"
- Confirm any permission dialogs that appear.

3. Connect the Device

- Plug your phone into your laptop via a USB cable.
- Allow USB debugging permission if prompted on your phone.

4. Build & Run the App

- Back in the Build Settings window:
  - Select your connected device from the Run Device dropdown.
  - Click Build and Run.
- Choose a folder to save the APK, and Unity will build and install the app on your phone.

5. Testing on Device

- Once installed, the app should launch automatically on your phone.
- Use touch or stylus input to interact with the AR environment (e.g., scaling, moving models).

6.3. Testing Result

6.3.1. Prefab Spawning

TC1.1.1: On tap, a prefab is spawned at the detected AR plane position.

Spawn Prefab on AR Plane: Allows the user to place a 3D object (prefab) into the AR environment by tapping on a detected plane. Ensures correct positioning, scaling, and orientation for immersive interaction.

Use Case: Spawn Prefab on AR Plane
Actor: User
Preconditions: AR session active, plane detection enabled
Main Flow:
1. User taps on screen where AR plane is detected
2. System checks if MAX_OBJECTS limit is not reached
3. System calculates spawn position (plane position + floatHeight)
4. System instantiates selected prefab
5. System applies correct scale based on prefab index
6. System orients object towards camera
7. System updates internal object tracking
Expected Output: Prefab appears at tap position with correct scale and orientation
Alternative Flow:
1a. No plane detected at tap position
- No object is spawned

TC1.1.2: Only allowed number of objects (e.g., MAX_OBJECTS = 2) can be spawned; further taps do not create more.

Enforce Object Limit: Prevents clutter by limiting the number of spawned objects. Ensures only a set number of prefabs can exist in the scene at once.

Use Case: Enforce Object Limit
Actor: System
Preconditions: MAX_OBJECTS objects already spawned
Main Flow:

1. User attempts to spawn new object
2. System checks current object count
3. System identifies oldest object
4. System removes oldest object
5. System spawns new object
Expected Output: New object appears, oldest object is removed
Alternative Flow:
1a. Object count is NOT at MAX_OBJECTS
- System spawns new object

6.3.2. Prefab Cycling

TC1.2.1: Pressing the cycle button updates the selected prefab and updates the UI text.

Cycle Through Prefabs: Lets the user switch between different object models available in the application, enhancing interactivity and exploration.

Use Case: Cycle Through Prefabs
Actor: User
Preconditions: Prefab list initialized
Main Flow:
1. User presses cycle button
2. System increments SelectedPrefabIndex
3. System updates UI text
4. System shows fade panel with new prefab name
Expected Output: New prefab selected, UI updated

TC1.2.2: Cycling wraps around after the last prefab.

Wrap Prefab Selection: Ensures smooth cycling through available objects. After the last prefab, selection wraps to the beginning to maintain continuity.

Use Case: Wrap Prefab Selection
Actor: System
Preconditions: Last prefab selected

Main Flow:
1. User presses cycle button
2. System increments SelectedPrefabIndex
3. System applies modulo operation
4. System updates to first prefab
Expected Output: Selection wraps to first prefab

TC1.2.3: Cycling triggers the fade panel with the correct prefab name.

Trigger Fade Panel on Prefab Cycling: Improves UX by displaying the name of the currently selected object through a fade-in animation panel when switching prefabs.

Use Case: Trigger Fade Panel on Prefab Cycling
Actor: User
Preconditions:
- AR session is active
- PrefabTextFader component is properly initialized
- At least one prefab is available in the prefabs list
- Current prefab is selected (SelectedPrefabIndex is valid)
Main Flow:
1. User presses the cycle button to change prefab
2. System increments SelectedPrefabIndex
3. System gets the new prefab name from prefabs[SelectedPrefabIndex].name
4. System calls prefabTextFader.ShowPrefabText(newPrefabName)
5. Fade panel displays the new prefab name
6. Fade panel animates according to its configured duration
7. Fade panel completes animation and becomes hidden
Expected Output:
- Fade panel appears with new prefab name
- Text is clearly visible
- Fade animation plays smoothly
- Panel disappears after animation completes

6.3.3. Prefab Deletion

TC1.3.1: Deleting an object removes it from the scene and updates internal data structures.

Remove Prefab from Scene: Allows the user to remove objects from the AR scene, freeing up space and managing scene clutter.

Use Case: Remove Prefab from Scene
Actor: User
Preconditions: Prefab exists in scene
Main Flow:
1. User triggers delete action
2. System removes object from scene
3. System updates internal tracking
4. System updates object spawn order
Expected Output: Object removed, internal state updated
Alternative Flow:
1a. Object doesn't exist
- System logs warning
- No action taken

Test Case	Use Case	Preconditions	Main Steps	Expected Result	Status
TC1.1.1	Spawn Prefab on AR Plane	AR session active, plane detection enabled	Tap on screen → Check object count → Calculate position → Spawn prefab → Apply scale & orientation	Prefab appears at tap position with correct settings	Passed

TC1.1.2	Enforce Object Limit	MAX_OBJECTS reached	Tap on screen → Identify oldest object → Remove oldest → Spawn new object	New object appears, oldest removed	Passed
TC1.2.1	Cycle Through Prefabs	Prefab list initialized	Press cycle button → Increment index → Update UI text	New prefab selected, UI updated	Passed
TC1.2.2	Wrap Prefab Selection	Last prefab currently selected	Press cycle → Increment index → Modulo operation applied	Prefab selection wraps to first item	Passed
TC1.2.3	Trigger Fade Panel on Cycling	AR session active, fade panel initialized	Press cycle → Update index → Fetch new name → Trigger fade panel	Fade panel displays prefab name with smooth animation	Passed
TC1.3.1	Remove Prefab from Scene	Prefab exists in scene	Trigger delete → Remove object → Update tracking and order	Prefab removed, internal state updated	Passed

CHAPTER 7

Conclusion and Recommendation

7.1. Conclusion

The integration of Augmented Reality (AR) in the medical field, particularly in the study and treatment of femur fractures, represents a significant advancement in both educational and clinical practices. This project aims to address the existing challenges in accurately diagnosing and understanding femur fractures by developing an interactive AR application that enhances the learning experience and improves patient outcomes.

Through this research, we have identified the limitations of traditional methods in providing the necessary precision for understanding femur anatomy and fractures. The proposed AR application is designed to fill this gap by offering real-time, high-resolution, 3D visualizations of femur fractures, allowing users to explore and analyse various fracture types in an immersive environment. This tool will not only aid in medical education by providing detailed anatomical information and fracture mechanics but will also support clinicians in making more informed decisions during diagnosis and treatment planning.

During the development of this project, I encountered several significant challenges. One of the most demanding aspects was learning a new application from scratch while simultaneously retracing previous development steps to integrate AR functionality. The lack of comprehensive documentation and limited knowledge of the three applications involved further complicated the process, causing delays and requiring considerable problem-solving. The most significant hurdle, however, was learning C# from the ground up, as it is the primary language used in this development. This steep learning curve posed a major obstacle but ultimately became an essential part of advancing the project.

In conclusion, the "Augmented Reality Exploration of Human Femur Fractures" project has the potential to revolutionize the way femur fractures are studied and treated. It bridges the gap between technology and medical science, providing a valuable resource for medical professionals, educators, and students. The project's emphasis on accessibility and innovation ensures that it will have a lasting impact on the field of medical education and practice.

7.2. Recommendation

The AR femur fracture application, while already functional, presents numerous opportunities for further enhancement. Based on user feedback and technical evaluation, several key areas for development have been identified. To begin with, the content library could be expanded to include a broader range of bone types and interactive elements. Incorporating real-world case studies and supplementary reference materials would greatly enhance the application's educational value while preserving its intuitive and user-friendly interface.

In terms of interactivity, the application could introduce several features to boost user engagement, such as controllable video playback for personalized learning pace, advanced note-taking with formatting options, tools for inserting images and drawings for annotations, interactive highlighting of bone structures for in-depth anatomical exploration, and an expanded quiz database offering various question types.

From a technical standpoint, improvements should focus on optimizing AR performance and ensuring system stability. Enhancing error handling and feedback mechanisms, refining data management and storage, integrating support for diverse device capabilities, and enforcing more rigorous testing and quality assurance processes would contribute to a more robust and reliable experience.

User experience can be further refined by streamlining navigation and simplifying interface interactions. Introducing more intuitive model manipulation controls, customizable learning paths, improved accessibility features, and enhanced visual feedback for user interactions would result in a smoother and more engaging experience.

To elevate the educational value of the application, structured learning modules should be developed alongside comprehensive assessment tools and progress tracking systems. Incorporating collaborative learning features and expert commentary would further enrich the learning process. Together, these enhancements would significantly improve the application's functionality, educational impact, and overall user experience while remaining aligned with its core goal as a medical learning tool.

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APPENDIX

Poster