# Application of Augmented Intelligence Technology with Human Body Tracking for Human Anatomy Education

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***Abstract*—Technological developments have a positive impact on humans to improve their abilities in line with innovations in the field of education which are increasing day by day. One of them is by increasing intelligence through collaboration between humans and technology called augmented intelligence. In this study augmented intelligence is applied to assist humans in studying human anatomy by utilizing augmented reality technology to perform motion tracking that can control 3D assets to follow it. The anatomy learning platform that was built was named AIVE (Artificial Intelligence on Virtual Education) with an architectural system consisting of a frontend for interface needs and AR platform development, there is also a backend for streaming databases and AI algorithms. Measurement of satisfaction and interest based on the PIECES framework is also carried out to determine the user's response to the platform being built. The results show a satisfaction level of 4.12 and an interest of 4.10 which means that users are satisfied and interested in the human anatomy tracking platform that is accessed via smartphones.**

***Index Terms*—Human anatomy, augmented intelligence, human motion.**

## I. Introduction

Human anatomy is the study of the structure of the human body which can be divided into several important parts. From the smallest to the largest, so it requires assistance in the form of tools to see it. The human anatomy is composed of many systems with distinctive features of different functions namely the cardiovascular system, digestive system, endocrine system, etc. Each system depends on and cooperates. The implementation of human anatomy is widely applied in various fields one of which is computer vision. Computer vision can use to track the human body's 2D or 3D perspectives to help humans with various functions and purposes.

The implementation of human body tracking in the field of medical education has become the interest of many researchers due to time limitations. So, an alternative is needed to facilitate learning without reducing the efficiency of knowledge absorption for students [1]. To facilitate distance learning that is not limited by time and does not require coming to the laboratory. The solution is needed to answer these problems based on medical scenarios [2]. Augmented intelligence technology is an alternative to improve and assist human work through collaboration between humans and technology [3]. In the initial implementation of the human anatomy platform, which was named the AIVE (Augmented Intelligence on Virtual Education) platform. We have succeeded in creating a human anatomy learning platform embedded in mobile devices. It has a choice of two operating systems, namely iOS and Android. Students can learn human anatomy through 3D animations that appear in each system anatomy scenario through personal devices. On this platform, there is a quiz with three levels to test students' understanding [4].

Another improvement on this platform is adding Artificial Intelligence (AI) to track the human body. AI can manage 3D assets according to the points and locations where the system should be placed. So that students can see 3D anatomy appear through real-time body tracking. Devices that support running this platform are slightly different from previous platforms. In this implementation, the devices that currently support are Apple products with a minimum A12 Bionic chipset to run properly. The SDK used to build this body tracking uses ARKit 4 and works on the rear camera, it already releases on Bionic A12. Through the device, students can manage the displayed anatomy assets by directing the device to recognize the human body when caught on camera.

The main contributions in this research are the design and implementation of human anatomy tracking platform to support virtual clinical practicum learning. Managing assets according to the rigging ARkit human body tracking SDK to be able to work properly by validating Joint Names, Relationships, and Orientation. Designs assets in standard T-pose and mesh bindings for best asset display performance. The concept of tracking real-time human anatomy. Feedback from the system and being able to access content stored separately from the platform. The content can be downloaded via the cloud to ease device performance. Various methods

Manuscript received November 4, 2021; revised December 15, 2021. This work was supported by Politeknik Elektronika Negeri Surabaya - Indonesia (PENS) under contract PELAKSANAAN PROGRAM RISET KEILMUAN TERAPAN DALAM NEGERI DOSEN PERGURUAN TINGGI VOKASI TAHUN ANGGARAN 2021 Numbers: 0761/D6/KU.04.00/2021 and Universitas Nahdlatul Ulama Surabaya - Indonesia (UNUSA) under contract Scheme 6 Numbers: 161.6.5/UNUSA/Adm-LPPM/III/2021.

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have been used to overcome this problem. One of which is by applying Artificial Intelligence technology to simulate intelligent behavior to help implement the learning that can be done remotely.

## II. Related Works

Previous research has carried out the development of a human anatomy learning module using augmented reality to study anatomy using statistical input assets. The asset can be manipulated through interaction using the user interface. This research has been implemented to medical students which are considered as an early-stage implementation. This research is also supported by the use of virtual reality technology on a medical learning platform [5]. Other research was also carried out by making a VR lab and VE integrated with HMD and HMG for an online learning system [6]. Research conducted by Muhammad Fajrul *et al* introduced the initial design of a platform Virtual Engineering that combines the Digital Twin concept and immersive experience. This research uses open source tools and affordable hardware, making easier for industry 4.0 planning to implement it. The platform consists of three parts, 3D Object Management, VE Module, and VE Interface. The developed platform has successfully demonstrated how physical devices can be integrated with their virtual models using the Digital Twin [7]. Gwo Jen Hwang *et al*. also created an AR-based learning platform with a game approach to support learning activities with QR code technology. Game players need to move in a real-world environment and find answers to in-game questions by observing the real-world environment [8]. Xiang *et al*. about the biology practicum learning system using augmented reality technology by depicting a 3D three-dimensional model microscope. In AR experiments it is done by defining a microscope image from a biology textbook or experimental course as a real object [1]. Nak Jun Sung *et al*. about the manufacture of physics simulators. These simulators are applied to educational institutions that use AR. Technology was built using OpenCV and OpenGL 4.5. to render the physics simulator model [9]. Cascals *et al*. create a simple game for high school students to solve math problems. The game uses virtual money that focuses on understanding and managing money, coins, and banknotes [10]. Frank *et al*. create innovations that involve comprehensively laboratory activities using vision, augmented reality, and MR-based measurement. This can be controlled on mobile devices [11]. Research conducted by Salmi *et al*. analyzes learning using augmented reality technology and aspects of motivation related to informal learning in Finnish students. The method used to analyze student behavior is through SEM path analysis. The results showed that AR technology looks promising to be used as a learning method to study abstract phenomena in a concrete way [12]. Chen *et al*. surveyed the AR platform that was built by dividing it into two categories, namely AR with concept maps and not. This platform is to find out the effectiveness of these platforms in answering student learning needs. Platforms with concept maps show better results, namely, students can improve results, motivation, and attitudes of mobile learning activities [13], [14].

Research conducted by Valentine Bazarevsky *et al*. on human pose estimation using a lightweight neural network implemented for fitness tracking and sign language recognition purposes [15]. The test was carried out using a Google Pixel 2 smartphone device named BlazePose. The resulting model can run in near real-time on the CPU of a mobile device and can be accelerated using the GPU. The resulting model has a topology of 33 key points. To determine the performance of the built model, this study compared it with OpenPose. Added a dataset consisting of an AR dataset consisting of various human poses, and a human when doing yoga activities. The results obtained by the BlazePose model require an increase in performance because it still lags behind OpenPose. The same study was also conducted by Ching-Hang Chen *et al*. to explore a neural network architecture. This research was implemented to predict ready-to-use 2D pose estimates using a probabilistic formulation approach. The probabilistic formulation that can be used as a basis for developing human 3D pose estimation [16]. Research conducted by Armelle Bauer *et al*. to solve problems in human anatomy using the Microsoft V2.0 Kinect device. This research builds Augmented Reality like a mirror to display 3D anatomy with improvements to the real-time experience [17]. The Kinect sensor is used to calculate the length and width of the user's body segment. The body segment is used to obtain a list of key points. From the use of this Kinect obtained 25 key point connection framework. This system design is designed for teachers who already have experience and knowledge of the clinical practice modules being taught. So that students can operate the modules according to procedures.When operating the module, the real object that becomes the focus is scanning the area to place 3D assets (plane detection). In this process, namely by finding horizontal and/or vertical planes in the real physical environment, depending on the activated detection mode. To facilitate distance learning with easy access requires technology that can answer needs based on medical scenarios. Virtual clinical practice is applied to mobile devices to overcome the limitations of time and practicum equipment used. One of which is clinical practice learning by using an anatomy module that focuses on human anatomy as a whole.

## III. Research Method

We present a new approach in the field of education, especially medicine. The approach is to make it easier to demonstrate and show important parts of the human body through augmented reality technology. The AR was built using ARKit SDK and RealityKit SDK to support human body tracking. The main contribution discussed in this session is about tracking a person's movement in the physical environment. Visualizing body movements using virtual characters that have been set according to RealityKit templates and AR platform scenarios. Platform development using Unity GameEngine tools with the help of AR Foundation SDK. The platform supports motion tracking, exposure estimation, environmental understanding, and user interaction [18]. Fig. 1 is the architecture of the AIVE V2 platform which is divided into three parts. First, educational institutions are a place for teaching and learning to be a place for testing. The modulewas tested on all medical students to find out their response to learning innovations using augmented reality technology. The AIVE platform is available in two operating system options, namely Android and iOS for the needs of supporting virtual clinical practice.

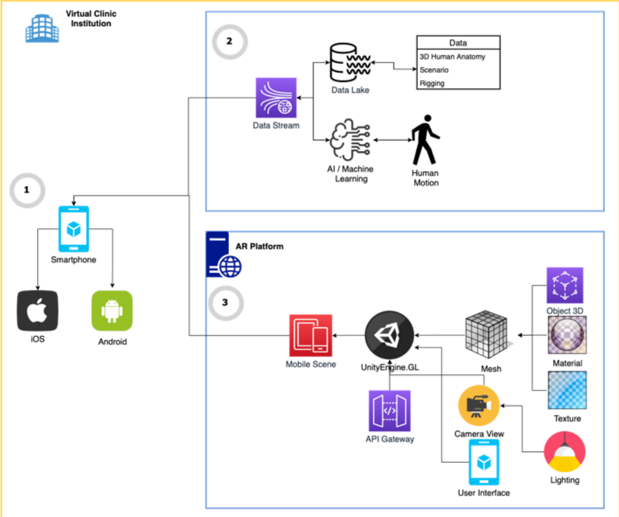


Fig. 1. Architecture AIVE V2 platform.

Second, it is a back-end for streaming data from human learning algorithms to track human movements. While a data lake is a collection of data. The data lake is managed in such a way based on certain conditions that are interconnected so that it is easy to manage. Through this management, users can more easily find information, store information, and dispose of information. This database is used to store 3D human anatomy assets, rigging on anatomy, scenarios, and object position management. Third, is the development of an AR platform in terms of front-end consisting of the user interface to present experiences using augmented reality technology. Mobile devices should at least have a vision sensor, motion sensor, and CPU powerful enough. The requirement must be fulfilled to ensure good performance and effective real-time computing. The platform is built with the IL2CPP backend for better application support across a wider variety of platforms. The AIVE platform uses on-premises servers to transfer data containing assets, transformations, meshes, and lighting.

### *A. AIVE V2 Platform Scenario*

The AR platform that was built adapts the needs of physical practicum by referring to the Anatomy ATLAS guidelines. To create a learning platform using AR, of course, virtual characters are needed to be displayed following human movements. Virtual characters hereinafter referred to as 3D assets, are organized into several sections based on the manual. The 3D asset settings are grouped by system, namely skeletal, muscles, nervous, lymphatic, digestive, and circulatory. Fig. 2 is 3D assets that have been grouped and then generate labels for each part to provide information to users. Each grouped system is built into a single scene using the Unity Game Engine.

A 3D asset arrangement consisting of 1602 objects with 385.754 polygons divided for men, and 400.799 polygons for women. This asset taken from Turbosquid is designed in a low polygon format for real-time plan needs such as AR, VR, and MR [19]–[21]. With specifications of 95% quads, 5% tris, and 0% n-gons specially designed for real-time use and better rendering. The following is a Pseudocode 1 of the human skeleton tracking scenario. We built it with the help of a few buttons to make it easier for the user.

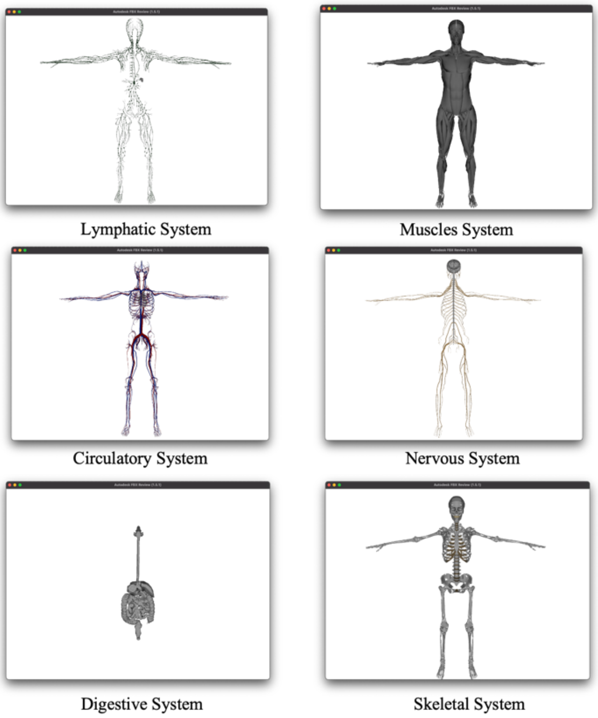


Fig. 2. Assets management.

**Algorithm 1:** Human Body Tracking Scenario

**Input:** Human Motion Skeleton
**Output:** Final Character Following Human Motion

```
begin
    switch
      bodyTrackingBool do
      case 0 do
        default;
      case 1 do MusclesSystem;
        ShowsMusclesAssets;
        subMenu = true;
      case 2 do SkeletalSystem;
        ShowsSkeletalAssets;
        subMenu = true;
      case 3 do DigestiveSystem;
        ShowsDigestiveAssets;
        subMunu = true;
      case 4 do LymphaticSystem;
        ShowsLymphaticAssets;
        subMenu = true ;
      case 5 do CirculatorySystems;
        ShowsCirculatoryAssets;
        subMenu = true;
      case 6 do
        NervousSystem;
        ShowsNervousAssets;
        subMenu = true;

  begin
    switch
      subMenu do
  –   case 0 do –
        BackButton;
        BacktoBodyTrackingScene;
      case 1 do
        ResetButton;
        resetBodyTracking = true;
      case 2 do
        PlayButton; playTracking
        = true;
      case 3 do
          PauseButton;
  –       pauseTracking = true;
```

The development of the AIVE V2 scene is divided into several scenes. There is the main scene which contains the first version of the platform with static asset input. The second scene is an introductory body tracking scene. Users can choose the anatomy system that is displayed with dynamic input that can be controlled through user movement. In the environmental understanding session by move the device to perform the mapping. The SLAM process occurs to read the relative position of the device [22], [23]. Used by providing control $u_t$ and IMU observation sensor $o_t$ with discrete time intervals t. Calculate agent status $x_t$ and environmental map $m_t$, so we get Equation (1).

The visual information from the inertial measurements of the IMU sensor is used to estimate the pose (position and orientation). The pose estimate between the cameras relative to the physical world over time. Where Bayesian rule is applied [18] to update posterior location parameters sequentially to detect feature differences visually.

$$P\,(m_{t+1}, x_{t+1} | o_{1:t+1}, u_{1:t}) \quad (1)$$

$$P\,(x_t | o_{1:t}, u_{1:t}, m_t) = \sum_{m_{t-1}} P\,(o_t | x_t, m_t, u_{1:t}) \sum_{x_{t-1}} P\,(x_t | x_{t-1}) P\,(x_{t-1} | m_t, o_{1:t-1}, u_{1:t})/Z \quad (2)$$

$$P\,(m_t | x_t, o_{1:t}, u_{1:t}) = \sum_{x_t} \sum_{m_t} P\,(m_t | x_t, m_{t-1}, o_t, u_{1:t}) P\,(m_{t-1}, x_t | o_{1:t-1}, m_{t-1}, u_{1:t}) \quad (3)$$

Visualization was done via the vision sensor by generating feature points to calculate location changes by providing a map and transition function $P(x_t|x_{t-1})$the Equation (2) is obtained. So the map can be updated sequentially based on Equation (3).

Before placing a 3D object on the surface, it is necessary to detect the plane by creating an imaginary line. The imaginary line contains a collection of points in a certain direction. It is used to retrieve information about the object's hit when Ray hits a physical object such as RigidBody provided by AR Foundation [24]. Using AR Foundation allows developers to build multiplatform augmented reality platforms in unity. AR Foundation is a set of MonoBehaviours and APIs built on top of the UI subsystem to generate various types of information. MonoBehaviour is the base class from which every C# Unity script is derived. This class provides a framework that allows developers to write scripts to GameObjects with the templates provided by MonoBehaviour. One of the advantages of AR Founda- tion that developers considered is that AR Foundation includes key features from Google ARCore, ARKit, Magic Leap, and HoloLens. As well as Unity's unique features for building AR applications that are ready for market. The existence of AR Foundation makes it easy for developers to bring features that are not widely available if only work on one platform. AR Foundation is a bridge between one platform and another. Based on that AR Foundation makes it easy to integrate each platform without rebuilding the AR application when it is brought into another platform. The display in the introduction to body tracking scene hereinafter referred to as M MainBodyTracking. The scene is designed to have a scene switcher that is used to move from the M MainBodyTracking scene to another AR system scene. The view of the M MainBodyTracking Scene can be seen in Fig. 3-A. with a button that makes it easier for users to find the anatomical system that needs to be displayed. The scene section of the AR system can be seen in Fig. 3. In this view, ARKit SDK is needed to recognize and track user movements through the rear camera of the iOS device. This scene is given four buttons that can be manipulated by the user. The first button is the pause button to delay or lock the AR Camera when reading the user's motion. This button can also be used to help the user when capturing a screen at a certain frame. The second button in this scene is a resume which is used to re-run AR Camera that has been delayed. The reset button is used to reset the camera's AR position and reading. There is alsoa return button that is used to move the scene from the AR scene back to the M MainBodyTracking scene. To be able to build an AR platform with dynamic input, not only scenes need to be prepared. Model setting based on ARKit's Motion Capture requirement is the main key in the development of this platform.


Fig. 3. User interface display human body tracking choice of anatomical system.

## B. Matching Model

Controls of virtual objects or models are adapted to certain hierarchies and naming conventions to function like a RealityKit mastermind. To conform to the RealityKit framework, the model was set using Maya 3D modeling software by placing the model in a standard T-pose. The Robot Model ARKit template has two important components, namely the body mesh and body skeleton. The oriented on the -Z axis, with the top oriented on the -Y axis, and the character'sleft hand the -X axis. The skeleton structure of the Robot Model cannot be changed unilaterally because it can affect the workingfunction of RealityKit. However, the body mesh component can be modified by importing 3D assets which are used as virtual objects. 3D assets are imported in standard T-pose. The pose, then manipulatedby changing the original position following the orientation of the ARKit Model Robot. Fig. 4 shows the orientation of the Robot Model ARKit and the orientation of the imported 3D assets. The imported 3D asset follows the default configuration of the Maya 3D modeling software. Modeling virtual objects to be able to work using the RealityKit framework also needs to be networked with the ARKit Robot Model. The model also adjusted to the orientation of the framework, although virtual objects do not have complete partslike the robot model.

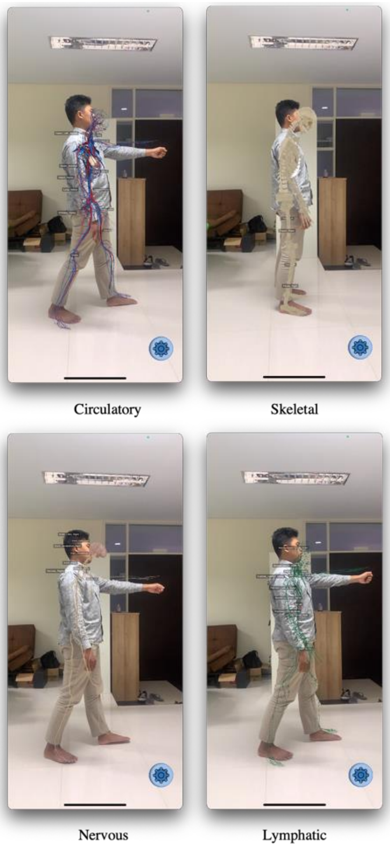


Fig. 4. Human body tracking display when tracking human movement.

The example in the digestive system does not have legs and arms that need to be moved. This does not pose an obstacle to tracking human bodies because virtual objects are bound in a single mesh. A single mesh contains all the connections needed in the correct ARKit hierarchy. Before exporting virtual objects for asset management on Unity Game Engine, virtual objects need to be validated. The validation against Joint Names, Relationships, and Orientations based on ARKit's required joint names. Fig. 5 shows virtual object joints that have been customized with ARKit's layout consisting of Torso, Head, Neck, Arm, Shoulder, Leg, Foot, Hand, and Fingers. Virtual objects that meet the criteria, then export the model into the FBX extension. The model with the FBX extension is compatible with Unity Game Engine.

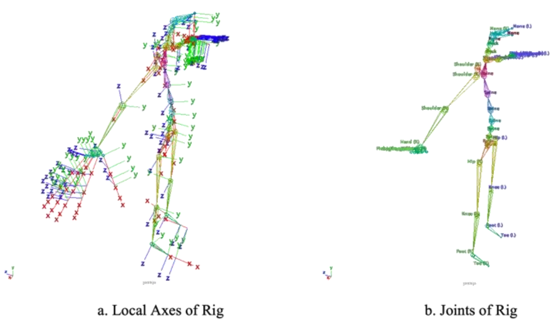


Fig. 5. 3D joint transform skeleton.

### C. *Human Motion Capture*

Human motion capture animate virtual characters based on player movements in real-time. This requires models that have mesh and bone structures such as ARKit and RealityKit templates. Fig. 6 shows how ARkit and RealityKit work. To be able to add virtual ob- jects to AR in the form of human anatomy models, `AnchorEntity` is needed [25]. The anchor entity to be able to activate `ARAnchor`. AR anchor is used to tracking the position and static orientation of human movement relative to the camera. `ARAnchor` is used to track single person, by activating `ARBodyTrackingConfiguration` [26]. AR Session can recognize person through rear camera by calling session `function(:didAdd:)`[27]. The use of anchors is also needed in ARKit to optimize the accuracy of world-tracking in the area around the anchor. Thus making virtual objects stay in place relative tothe real world. Anchor also supports changes in human position during the tracking process by removing the appropriate anchor. Appropriated anchor from the initial position to the updated final position every frame. `AnchorEntity` instances are used as roots of hierarchical entities. Then add them to the anchor collections for instances to Scenes which allow ARKit to add hierarchical-based virtual models to view scenes. So RealityKit can embed virtual content into the real world such as surfaces or images via specific anchor points.

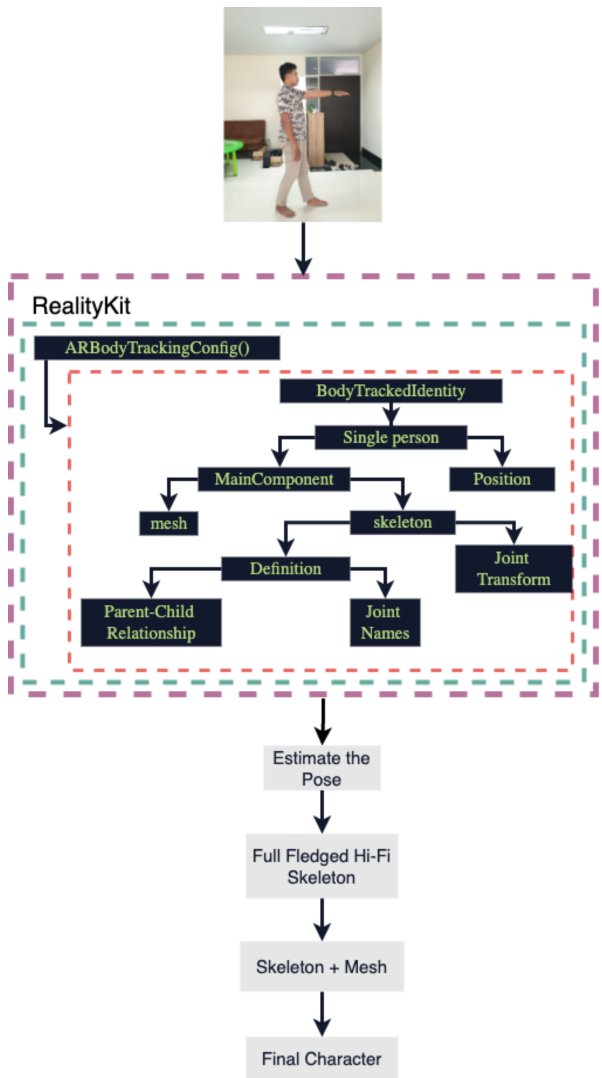


Fig. 6. ARKit and RealityKit capturing body motion in 3D.

### D. *Place Object Virtual on Human Surface*

To be able to place virtual objects onto the surface can be doneby accessing the `skeleton` [28]. The skeleton consists of the nodes representing the joints, and the edges representing the bones. All movements of bones follow the moving and related parent. Placement of objects to be able to occlude with the human body starts from reading the `ARBodyAnchor` data [29]. This data which there is a set of relationships and measurements between lines, angles, and surfaces.

Table I is a snippet of information on every relationship between parent and child on a joint. Every joint is interconnected to perform movement based on human motion control. The numbering of each joint shows the index of the relationship with the parent. For example, the root does not have a parent because the root is set as the main parent in the skeleton. Fig. 7 represents how ARKit works on our platform. ARkit works by capturing a single person combined with virtual characters. So that ARKit skeletons can track human movements in real-time.

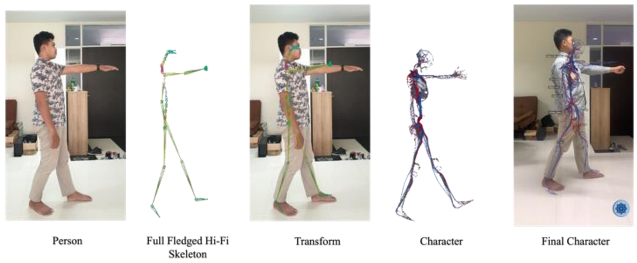


Fig. 7. Track a person in the physical environment.

TABLE I: RELATIONSHIP BETWEEN PARENT AND CHILD IN EACH JOINT

| Parent | Child | Parent | Child |
|---|---|---|---|
| Root = 0, | parent: <none> (-1) | LeftHandThumbEnd = 46, | LeftHandThumb2 (45) |
| Hips = 1, | Root (0) | Neck1 = 47, | Spine7 (18) |
| LeftUpLeg = 2, | Hips (1) | Neck2 = 48, | Neck1 (47) |
| LeftLeg = 3, | LeftUpLeg (2) | Neck3 = 49, | Neck2 (48) |
| LeftUpLeg = 2, | Hips (1) | Neck4 = 50, | Neck3 (49) |
| LeftLeg = 3, | LeftUpLeg (2) | Head = 51, | Neck4 (50) |
| LeftFoot = 4, | LeftLeg (3) | Jaw = 52, | Head (51) |
| LeftToes = 5, | LeftFoot (4) | Chin = 53, | Jaw (52) |
| LeftToesEnd = 6, | LeftToes (5) | LeftEye = 54, | Head (51) |
| RightUpLeg = 7, | Hips (1) | LeftEyeLowerLid = 55, | LeftEye (54) |
| RightLeg = 8, | RightUpLeg (7) | LeftEyeUpperLid = 56, | LeftEye (54) |
| RightFoot = 9, | RightLeg (8) | LeftEyeball = 57, | LeftEye (54) |
| RightToes = 10, | RightFoot (9) | Nose = 58, | Head (51) |
| RightToesEnd = 11, | RightToes (10) | RightEye = 59, | Head (51) |
| Spine1 = 12, | Hips (1) | RightEyeLowerLid = 60, | RightEye (59) |
| Spine2 = 13, | Spine1 (12) | RightEyeUpperLid = 61, | RightEye (59) |
| Spine3 = 14, | Spine2 (13) | RightEyeball = 62, | RightEye (59) |
| Spine4 = 15, | Spine3 (14) | RightShoulder1 = 63, | Spine7 (18) |
| Spine5 = 16, | Spine4 (15) | RightArm = 64, | RightShoulder1 (63) |
| Spine6 = 17, | Spine5 (16) | RightForearm = 65, | RightArm (64) |
| Spine7 = 18, | Spine6 (17) | RightHand = 66, | RightForearm (65) |
| LeftShoulder1 = 19, | Spine7 (18) | RightHandIndexStart = 67, | RightHand (66) |
| LeftArm = 20, | LeftShoulder1 (19) | RightHandIndex1 = 68, | RightHandIndexStart (67) |
| LeftForearm = 21, | LeftArm (20) | RightHandIndex2 = 69, | RightHandIndex1 (68) |
| LeftHand = 22, | LeftForearm (21) | RightHandIndex3 = 70, | RightHandIndex2 (69) |
| LeftHandIndexStart = 23, | LeftHand (22) | RightHandIndexEnd = 71, | RightHandIndex3 (70) |

## IV. EXPERIMENTAL RESULTS

This chapter describes the experimental results of the development platform by measuring the performance. The platform was measured when it is implemented in a medical education institution. This assessment is needed to determine the technical capabilities, operational implementation, and platform utilization. Satisfaction and interestlevel analysis on AR AIVE platform focuses on the performance of the software when it is run. So the focus of this analysis is used to find out the user's view of the performance of the platform. The method used for this analysis is the PIECES Framework. It consists of (Performance, Information and Data, Economy, Control and Security, Efficiency, and Service) with a value range and indicators as shownin Table II. The test results are focused on the satisfaction and interest of the platform in answering user problems when running the application. The platform assessment starts from the login system to the body tracking experiment which is implemented to study human anatomy. Data collection was taken from 30 respondents through a Google Form. The form contains any question that students must answer with a concentration of medical education. The students are from Universitas Nahdlatul Ulama Surabaya (UNUSA) with a total of 29 questions. Table III is a summary of questions from the questionnaire given.

TABLE II: AVERAGE OF INTERESTS AND SATISFACTION

| Value Range | Interests | Satisfaction Predicate |
|---|---|---|
| 1 - 1.79 | Very Not Interest | Very Dissatisfied |
| 1.8 - 2.59 | Not Interest | Not Satisfied |
| 2.6 - 3.39 | Sufficiently Interest | Sufficiently Satisfied |
| 3.4 - 4.91 | Interest | Satisfied |
| 4.92-5 | Very Interest | Very Satisfied |

TABLE III: RESULT OF PIECES FRAMEWORK INTEREST AND SATISFACTION PREDICATE

| | Interest | Satisfaction |
|---|---|---|
| Performance | 4.09 | 4.10 |
| Information and Data | 4.11 | 4.20 |
| Economics | 4.08 | 4.10 |
| Control and Security | 4.06 | 4.08 |
| Efficiency | 4.18 | 4.09 |
| Service | 4.08 | 4.18 |

The results of data processing on average satisfaction and interest got a good response. Students agreed that this platform provided satisfaction from the point of view of the newest anatomy learning technology. This platform is interesting to be developed to provide more interesting and different learning. Students also get experience so that learning is more interactive and fun. From the results of the

PIECES Framework data processing. The average value of interestis 4.10 and the average value of satisfaction is 4.12. It means that students are interested in our platform and are satisfied with theperformance of the platform.

The AR platform with artificial intelligence has been equipped with a quiz mode. Quiz mode is used to test students' understanding of anatomy learning. In the quiz mode, there are three levels, namely easy, medium, and hard. The difficulty level scenario has passed the teacher's consideration. In quiz mode, students are asked to answer questions related to anatomy. Before answering the quiz, students were asked to take advantage of the learning mode.

From the results of the understanding test through the mode for AR users, the average value is shown in Table IV. At the easy level, the average is 94.46, the medium level is 90, the hard level is 83. While the results of the comprehension test through non-AR, namely using a paper-based test, the average value is obtained as shown in Table V. At the easy level, the average is 92.53, the medium levelis 86.2, the hard level is 79.8. This means that the level of student understanding can be increased through the use of AR technology when compared to just reading a book. The use of AR technology can be used to improve student understanding.

TABLE IV: STUDENT ACHIEVEMENT SCORE RESULTS WITH AR

| | # of students with AR | | |
|---|---|---|---|
| range | easy | medium | hard |
| 66-70 | 0 | 0 | 2 |
| 71-80 | 0 | 0 | 11 |
| 81-100 | 30 | 30 | 17 |
| average correct score | 94.46 | 90 | 83 |

TABLE V: STUDENT ACHIEVEMENT SCORE RESULTS WITHOUT AR

| | # of students without AR | | |
|---|---|---|---|
| range | easy | medium | hard |
| 66-70 | 0 | 3 | 7 |
| 71-80 | 8 | 7 | 9 |
| 81-100 | 22 | 20 | 14 |
| average correct score | 92.53 | 86.2 | 79.8 |

## V. CONCLUSIONS

This study presents the implementation of a human anatomy learning platform. This platform utilizes ARKit body tracking technology to build 3D human motion to make it easier for students. Students can learn the structure of human anatomy through interesting augmented reality technology. The development of this platform aims to present an interactive and interesting impression when studying the structure of the human body. This platform can be run using a smartphone with a choice of the iOS operating system. The results obtained from processing scores based on the questionnaire the average value was 4.10 for the level of interest and 4.12 for the level of satisfaction. Theresults using the PIECES Framework resulted in a positive response. Students were satisfied and agreed that the AR AIVE platform was interested to be used as a virtual practicum module.

This research also makes it easier for students to study anatomy. The anatomy has been grouped by organ system and its division according to the anatomical atlas. The system is also equipped with labels in each part, including the smallest part to maintain informative learning and present an immersive impression. To attract students' attention and motivation in learning. The use of the AR platform is also able to improve learning outcomes when compared to without AR. Thus, it is hoped that learning using augmented reality technology can be designed for educational purposes. While still paying attention to every content and content that is loaded must be carefully conceptualized. Including designing other virtual practicum learning modules by following current technological developments, all of which are virtual. to achieve self-study targets.

## VI. LIMITATION AND FURTHER INVESTIGATION

This study discusses human motion tracking to be applied in learning human anatomy. In this study, some limitations need to be corrected which impact students' understanding. One thing that can be done is to increase the level of difficulty that varies based on the teacher's recommendations. Increasing the difficulty level aims to test students' understanding and get better results. Also, the development of the platform can be done for other case studies related to human body tracking, especially in the field of education. Development can be done on the deployment platform to be used in various operating systems.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

Conceptualization, S.S., U.H.A.R., and R.P.N.B.; methodology, E.D.F., S.S.,; validation, S.S., U.H.A.R., and R.P.N.B.; resources, S.S., and R.P.N.B.; data curation, E.D.F.; writing---original draft preparation, E.D.F., I.A.A., N.A.S., and A.L.H.; writing---review and editing, E.D.F., S.S., U.H.A.R., and R.P.N.B.; 3D optimization, E.D.F., A.L.H.; human anatomy validation, B.E.S.: supervision, S.S., U.H.A.R., R.P.N.B., and B.E.S.,; project administration, R.P.N.B.; funding acquisition, S.S., R.P.N.B.; All authors have read and agreed to the published version of the manuscript.

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