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Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

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STANCEUP: POSTURE DETECTION AND MONITORING DEVICE FOR BEGINNER LEVEL TRAINING OF TAEKWONDO POOMSAE USING KINECT AND IMU SENSORS THROUGH CONVOLUTIONAL NEURAL NETWORKS (CNN)

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APPROVAL SHEET

This project study entitled **"Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)"** has been approved and submitted by the following proponents:

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In partial fulfillment of the requirements for the degree of **Bachelor of Science in Electronics Engineering** is hereby recommended for approval.

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ABSTRACT

Poomsae Taegeuk is a form of Taekwondo that involves a series of movements and poses that require precision and fluidity. While the scoring and training system for Poomsae is based on general guidelines, inconsistencies and bias can arise due to the subjective nature of the judges' perception. Moreover, the lack of technology-based training systems for Poomsae makes it challenging to develop an objective and scientific basis for training. To address these challenges, this project involves a self-training system to monitor and detect Poomsae execution posture. The system utilizes a combination of Inertial Measurement Unit (IMU) data from the wearable device, placed on the wrists, ankles, and core, and visual data from the Kinect v2 system. The data is fed to the CNN Machine Learning (ML) model to objectively score Poomsae movements. This is focused on beginner-level Poomsae, specifically Taegeuk 1 to 4, to notify beginner athletes of their performance and improve their competence in this sport. The wearable devices use Wi-Fi Module to send data acquired by the IMU to a locally hosted database. Athletes can view their performance statistics through the developed Desktop application.

The dataset created for the system is recorded executions done by four (4) experienced Taekwondo student-athletes of different heights. Further considerations for the dataset recording are through continuous movement repetition and repetitions of each specific movement, respectively. Based on the data gathering and algorithm testing, the project reached the highest accuracy percentage of 70%. Furthermore, the classification process of the developed algorithm for the system takes several minutes, depending on the size of the input file. With this accuracy, together with the increased functionality of the IMU sensors and Kinect v2, it allows the overall system to enhance Taekwondo athletes’ Poomsae performance without coach-dependent training and scoring.

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- **Team StanceUP**

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CHAPTER 1

THE PROBLEM AND ITS SETTING

Chapter 1 features the problem, background, and its setting to provide how the study was accomplished. This includes the Introduction, Background of the Study, Research Gap, Research Objectives, Significance of the Study, Scope and Limitations of the Study, and the Definition of Terms.

1.1: Introduction

Taekwondo is the Korean art of self-defense which is an international martial arts sport conducted in 210 countries worldwide as an official Olympic sport. It is known for its emphasis on kicking techniques compared to other types of martial arts [1]. Before learning potential combat techniques, Taekwondo players are required to learn certain forms called Poomsae. Poomsae is a combination of techniques of blocks, stances, kicks, and attacks performed consecutively against imaginary opponents while moving in certain directions [2]. Specifically, it is the Taegeuk series of Poomsae that is recognized by the World Taekwondo Federation for rank promotion. With the fact that learning these moves by doing them repetitively allows players to demonstrate more complex techniques, Poomsae is usually learned in order according to belt rank [3]. In general, trainees need to successfully perform the eight Taegeuk Poomsae to gain the black belt which is the highest level in the ranking system [4].

Posture is essential, especially to athletes as it affects their performance, bio-motor and bio-mechanical ability, and the occurrence of injury. In sports, correct posture comes from base control, as it allows the athlete to perform functional movements, such as running, jumping, or throwing. However, it also leads to an unbalanced ratio of quadriceps to hamstring length, due to muscle strengthening exercises [5].

In Taekwondo, posture is particularly important to improve balance and the power level of the athletes' kicks [6]. Proper posture is needed to execute different techniques in Taekwondo. Through body strengthening (i.e., lifting weights) athletes can improve their posture. Through training, athletes can improve their rhythm when it comes to transitioning between relaxed and stiff posture [6].

The principal key positions in taekwondo are the stances, and the transitions applied are important to movements and techniques practiced by the athlete. It is composed of the body weight distribution and foot orientation when attacking, defending, advancing, or retreating. Without proper body positioning in relation to force, weight distribution, and direction alteration, the techniques, skills, and movements will be compromised [7].

With that being said, this study aims **to enhance the practice of Poomsae in Taekwondo training by effectively utilizing sensors and machine learning techniques to monitor and detect postures.**

Using posture analysis or assessment, the posture of a person can be evaluated in a position integrated in a manner related to the ideal posture. This can be assessed while performing sports activities using modern techniques: 1) Visual observation method, 2) Plumb Line Method, 3) Goniometry, 4) Photographic and Digitalization Method, 5) Radiographic Method, and 6) Photogrammetric method [8]. In line with this, the proponents utilized a photogrammetric-like method through the Kinect V2 sensor as it provides quantifiable body tracking data. This method is beneficial in analyzing static and dynamic postures of different athletes, incorporating better techniques that can enhance their performance.

1.2: Background of the Study

The goal of the study is to create a monitoring and detection system for Poomsae posture self-training using data and parameters from hybrid sensors. This goal is to answer the problem statement stated in the previous segment.

With that goal in mind, the features that were put into consideration in the filtering process of the RRLs compiled connected to the topic are as follows:

1. Monitoring and recognition of motion (or pose)
2. Usage of Hybrid Sensing (Inertial Sensors and Visual Sensors) and data fusion
3. Taekwondo Posture Detection
4. An integrated software application for the monitoring process.
5. Machine Learning or Deep Learning Algorithms

In the process, the researchers narrowed their related studies down to seven (7) that are best related to the goal stated.

Cunha et al. [9] emerges as the most relevant study found, satisfying all the specified criteria. This study uses a combination of a 3D Orbbec Camera for motion analysis and the IMU sensors (GY 521 MPU 6050) that are used to avoid occlusions. From the data provided by the sensors, a database was created which undergoes deep learning for classifying the motion. It tested different models and concluded that a Convolutional Neural Network (CNN) combined with Long Short-Term Memory (LSTM) or CNN+LSTM model is the most accurate model due to its 93% yielded accuracy. Additionally, it only has four (4) classes: rear leg bandal, front leg bandal, jirugui, and front leg miro; with about two hundred samples per class. The mobile app also contains just a summary of the time spent, the number of movements performed, and their success rates [9]. Although the study was already published, the project needs further iterations and development to achieve a working real-time system for Taekwondo athletes.

In [10], their network is called DeepFuse, a two-stage fully 3D network used to estimate human poses by fusing data from IMUs and multi-view images. It uses multi-channel volume and random shut in the pre-processing of the visual data gathered from eight cameras. The network of the DeepFuse is composed of Hourglass Network modified to be a 3D CNN for feature extraction and classification; a soft-argmax layer is implemented to overcome low-resolution frames of the voxel. Lastly, for the training system, the RMSProp optimizer is used.

In 2015, a study on Multi-Modal Dataset was published in an IEEE journal [11]. The researchers of this paper successfully created a comprehensive dataset of 27 human actions. The dataset, now referred to as the UTD Multimodal Human Action Dataset (UTD-MHAD), was formed by fusing wearable devices with 9-axis MEMS sensors and a Microsoft Kinect camera. They utilized four data modalities, including RGB videos, depth videos, skeleton positions, and inertial signals comprising acceleration and rotation signals. In relation to the UTD-MHAD, another Multi-Modal HAR dataset was created in a study in 2022. However, this was created using a Microsoft Kinect V2 and ten wearable devices with MPU 9250 sensors and only utilized depth video, skeleton positions, and inertial data to represent 22 human actions [47].

A study in 2020 utilized the UTD-MHAD as one of its benchmark datasets to create a Multi-Modal Human Action Recognition (HAR) Model [12]. The developers of the study created a total of five CNN and LSTM models for the angle-velocity feature, angle feature, optical feature, still image, and signal diagram from the inertial sensors. These five models were combined to create an ensemble, or a fully connected layer, for the inception process.

The overall accuracy of the created multi-modal action recognition algorithm was found to be 0.991 for UTD-MHAD.

In a study made by Jang et al [13], the usage of only IMU (9-DOF) sensor modules is utilized to detect and classify anomalous kicks from normal kicks. The placement of the sensors is on the spine, pelvis, and left and right foot of both the participants in the sparring game. The deep learning neural network used is CNN, specifically Keras' sequential model that uses the AI model Adaptive Moment Estimation (ADAM) for training. This model yields a 97.5% accuracy rate.

TUHAD [14] is a dataset consisting of multimodal image sequences of Poomsae actions which is used for action recognition. The setup involves utilizing two Kinect V2 devices alongside a CNN action recognition architecture based on key frames. The proposed architecture uses existing CNN-based action recognition architecture; for the activation function, the hidden layers were used as the rectified linear unit (ReLU). Additionally, it uses an ADAM optimizer to train the parameters. This proposed system is created to accommodate the low recognition rate in translational actions of the referenced methods. From its results, the combination of depth image modality and RGB produced the highest accuracy of 87.7% in the front view and 94.2% at the side view. The scope of this study is confined to the initial three chapters of Poomsae Taegeuk, encompassing approximately 100,000 image sequences of eight basic unit techniques of taekwondo. Moreover, these sequences were captured against two different backgrounds [14].

Another study that uses only the Kinect V2 sensor is [15]. In order to enhance the accuracy of motion detection by the sensor, this study incorporates additional technologies such as iPiSoft and Optitrack. It also compares different algorithms, such as Multilayer

Perceptron (MLP), Naive Bayes, and Decision Tree, in recognizing the motion; with MLP showing the highest accuracy in detecting simple motion (97.2%) and complicated motion (96.3%). It also includes a pointing system for each form it detects that abides by the Taekwondo Poomsae competition rules [15].

1.3: Research Gap

In sports, the conventional process of evaluating the athletes' performance has been manually done or based on the judgment of the coaches. For this reason, monitoring systems were developed to help in giving accurate feedback on the athletes' performance. In the case of Taekwondo, inertial measurement units (IMUs), optical motion capture systems, and Machine Learning have been utilized for this objective. However, most proposed systems are intended for the assessment of the sparring category of the sport and use either IMUs or MoCap using cameras. Thus, the development of a system that enables posture monitoring and detection for Taekwondo Poomsae training using both IMU sensors and Kinect through Convolutional Neural Networks (CNN) was proposed. In addition to this, the proposed system also makes posture improvement possible using visual materials (i.e., images and videos with text descriptions) and performance analysis (i.e., scores) as seen on the software application.

1.4: Research Objectives

The general objective of this research is to notify the Taekwondo athletes of their performance in Poomsae, specifically Taegeuk 1 to 4, and increase their competence in this sport. This will also provide a scientific approach to performing the said sport.

These are the following specific objectives of this research:

1. To develop a system that will monitor and collect posture parameters (i.e., angular velocity, angles, angles, orientation, and skeletal data) using the combination of

data from Kinect and the wearable device.

2. To develop a desktop application that includes features for training and tracking an athlete's performance, integrated with a database system.
3. To develop an identifying machine learning model that utilizes CNN-LSTM (Long Short-Term Memory Networks) models.
4. To test the device on athletes and perform user acceptance tests anchored on ISO/TC 83 and ISO 9126.

1.5: Significance of the Study

The usage of wearable technology has been exploding not just in the professional sporting arena (where the demands were higher) but also in helping and quantifying fundamental parts of our everyday life.

Self-monitored training and quantifying the performance of athletes using wearables helps in a faster-paced improvement. Usage of wearable technology helps in getting more objective and quantifiable results that accurately depict the specific things the athletes need to focus on.

The study will also enhance knowledge in using different sensors and the difference in results using a hybrid network of sensors. Additionally, the study would contribute added information to monitoring systems with data fusion technology. Lastly, with the aid of this study, improvements, and new possibilities regarding the usage of sensors may be developed for further research.

The study would also help in improving Annex 29: Industry, Energy and Emerging Technology Roadmaps under the Ubiquitous / Pervasive Computing Technology Cluster of the HNRDA by focusing on Sensors and Machine Learning in the System. Furthermore, this study can also contribute towards the achievement of Sustainable Development Goal (SDG) 9, specifically target 9.5, which focuses on enhancing scientific research and upgrading the technological capabilities of various industrial sectors.

1.6: Scope and Limitations

This project study focused on monitoring and detection of the posture of Taekwondo Athletes performing Poomsae, specifically Taegeuk. The researchers chose to benchmark the prototype on Experienced Student Taekwondo Athletes from the Technological University of the Philippines - Manila. Additionally, the researchers chose to do the data gathering and prototype testing on beginner and aspiring Taekwondo Athletes from the same university as it is convenient and beneficial for their alma mater. The time allotment for this project study is one year, from July 2022 to July 2023.

The relevant papers of this study [1,14] focused on Poomsae specifically for major movements of Taegeuk and Koryo. However, the researchers chose to focus only on Taegeuk Levels 1 to 4 due to the time constraint given to them and the many numbers of movements involved in this specific Poomsae type. The Taegeuk Levels 1 through 4 cover basic stances, blocks, and kicks. The breakdown of the number of movements per level can be found in Table 1 below. Lastly, the proponents want to put emphasis that the project study does not wish to replace Taekwondo coaches and that the coach’s expertise in Poomsae training as it is a system that is open to future improvements and developments.

Table 1. Taegeuk Levels and Number of Poomsae Forms per Level

Taegeuk Level	No. of Major Techniques	No. of Specific Movements
Taegeuk 1	16	8
Taegeuk 2	18	10
Taegeuk 3	20	22
Taegeuk 4	20	16
Taegeuk 5	20	21
Taegeuk 6	21	22
Taegeuk 7	25	16
Taegeuk 8	24	21
Total:	**164**	**136**

1.7: Definition of Terms

IMU Sensors - An Inertial Measurement Unit (IMU) typically includes three gyroscopes oriented in mutually orthogonal directions, three accelerometers oriented in mutually orthogonal directions, and usually a three-axis magnetometer. [20]. The term "Inertial" is employed because the sensors in question utilize the principle of inertia to measure and provide readings related to velocity, acceleration, and magnetic fields. The combination of the sensors, gyroscope, accelerometer, and magnetometer, makes the IMU suitable for the measurement and analysis of a body or an object's posture.

KINECT - A visual recognition controller is designed to identify and track the movements of individuals based on the images captured by a camera. It incorporates the ability to detect depth through an infrared ray projector. This controller demonstrates high accuracy as it can recognize not only the movements of the arms and legs but also facial expressions. It finds applications in areas such as dance and game fitness, where it can be used effectively.

Motion Capture - Motion capture technology records and translates the movements into data that can be read and applied to a 3D model. There are different types of motion capture devices, which are classified into two categories, optical and non-optical systems. This study uses optical systems such as RGB-D cameras, which include KINECT, and non-optical systems which include IMU under the inertial systems.

Poomsae - Poomsae is a series of basic attack and defense movements put together in a pattern and performed against imaginary opponents. It can be practiced and trained, even without the presence of an instructor, in accordance with the fixed patterns.

Posture - Posture refers to a dynamic and ever-changing pattern of reflexes, habits, and adaptive responses that are employed to maintain an upright and functional state in the face of various challenges. It is the form of the body that is made up of proper positioning of bones, joints, muscles, and nerves. Stances in Taekwondo are the foundation of offensive and defensive moves. Proper stance and posture play a significant role in correctly performing any kick, punch, or block in Taekwondo. For this study, it can be additionally defined as the combination of relaxed and stiff postures during the execution of Poomsae.

Taegeuk - A set of Poomsae that is used to build the foundation in taekwondo. It is a form that has a detailed pattern of attack-and-defense movements and techniques that are used in traditional martial arts. The table below shows the belt levels, and a number of unique, major, and specific movements of Taegeuk Poomsae.

ISO 9126 - An ISO standard that provides a comprehensive framework and guide for evaluating developed software by considering its functionality, reliability, usability, efficiency, maintainability, and portability. By considering these factors, the developers and creators of the software can assess, refine, and improve their products.

ISO/TC 83 - ISO standards are developed in collaboration with the Technical Committee (TC) responsible for creating and maintaining standards related to sports and recreational equipment. These standards provide a common framework and guide for manufacturers, developers, regulators, and users in the sports field. Their purpose is to ensure that products, particularly equipment and training apparatus, meet established quality and safety requirements.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Chapter 2 presents the related literature and studies. In this chapter all significant studies, findings, and conclusions are cited from the gap of knowledge stated in the previous chapter.

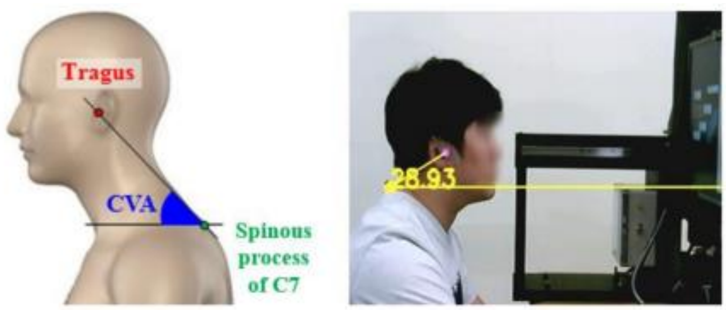
2.1 Posture

Posture is defined as the body position held by a person while standing, sitting, or lying down. Proper posture is especially important as it reduces strain on muscles and ligaments while performing activities [16]. It can provide numerous benefits such as increased energy, enhanced confidence, relief from neck strain, migraine relief, prevention of back and shoulder problems, and assistance for chronic back pain. Good posture is characterized by placing the body in a position of minimum stress on the joints and muscles. On the other hand, bad or incorrect body posture is defined as any position that increases stress on the joints. In a study, exercise has shown a positive effect on body posture. It also indicates that the best way to improve posture is by focusing on exercises that can strengthen or improve the core, lower back muscles, spine, and pelvis.

2.1.1 Existing Technologies and Systems for Posture-Correction

Due to technological advancements, posture corrections can now be done with the help of technology. There is a study conducted to compare posture and neck fatigue. It uses Flexion Relaxation Phenomenon (FRP) and Craniovertebral Angle (CVA) as monitoring types to compare posture to neck fatigue level quantitatively. This study required a custom-made monitor system that could move in any direction. In general, the mobile monitor exhibited superior performance compared to the fixed/stationary monitor, suggesting that these types of monitors can assist in reducing neck fatigue [17].

The use of a wearable sensor designed to correct head and neck posture has proven to be highly effective in reducing the strain on the neck caused by poor posture while sitting or standing at a desk. The objective of this study was to investigate the influence of a wearable posture sensor on the posture of the head and neck, as well as the physical demands associated with office work. As shown in Figures 1a-1b, the measurements conducted in this study involved determining the angles of head and neck flexion, quantifying the gravitational force acting on the neck, and assessing the positions of different components within the workstation [18].



(a) *Craniovertebral angle (CVA);* **(b)** *Open-source computer vision (OpenCV).*

Figure 1a-b. *Measurement for neck posture using wearable posture sensors*

(Source: https://doi.org/10.3390/ijerph17176345)

There is also a study on the posture correction system using an inertia sensor-based guidance system or IMU. This is used in stroke rehabilitation which is a labor-intensive and time-consuming activity. In Figure 2, a wearable system incorporating vibrotactile actuators is employed to measure and rectify arm posture by comparing it to a reference point and providing vibration-based feedback [48]. The results of the experiments demonstrated the system's resilience and its ability to replicate different postures more effortlessly based on their inherent naturalness.

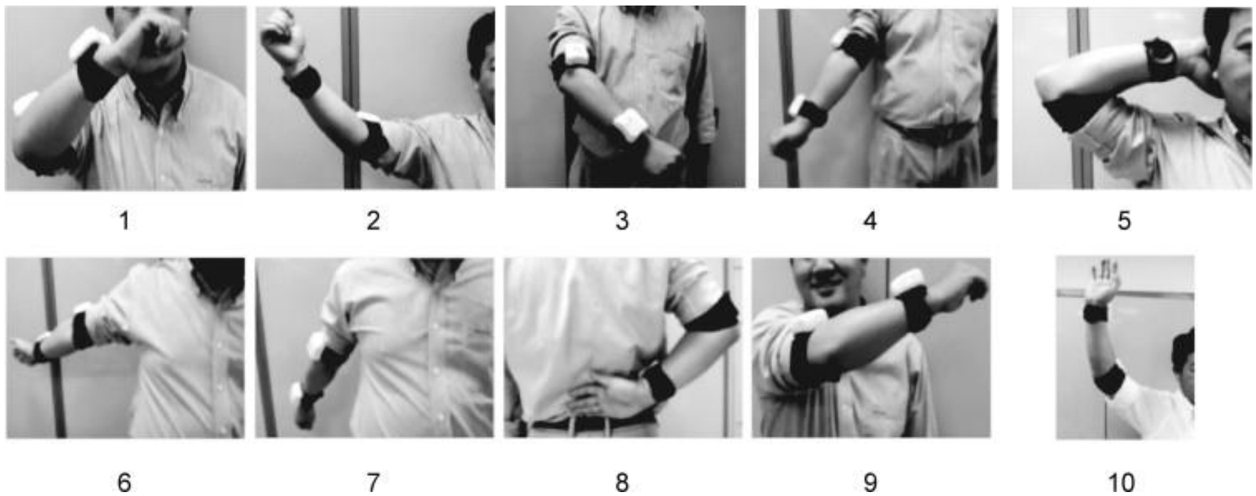


Figure 2. *Inertia sensor-based guidance system for upper limb posture correction*

(Source: https://doi.org/10.1016/j.medengphy.2011.09.002.)

2.1.2 Posture-Correction in Combat Sports

Another aspect of posture correction can be applied in combat sports. This is due to the importance placed on posture in the proper execution of a lot of combat sports. The research investigates the implementation of computer vision-based virtual reality technology for correcting sports postures. It examines the fundamental concept of computer virtual reality and explores its application in rectifying sports movements. The corrective exercises chosen are determined by the daily incorrect exercises. The results of the experiment show that there is a substantial difference between the experimental group before and after the squat test. It uses image processing. The primary aim of image preprocessing is to ensure the accuracy of the subsequent image input. It involves consolidating variations in the raw image, adjusting coordinates, and enhancing or preserving the image with flawed graphics. The device and its workflow are depicted in Figure 3 [19].

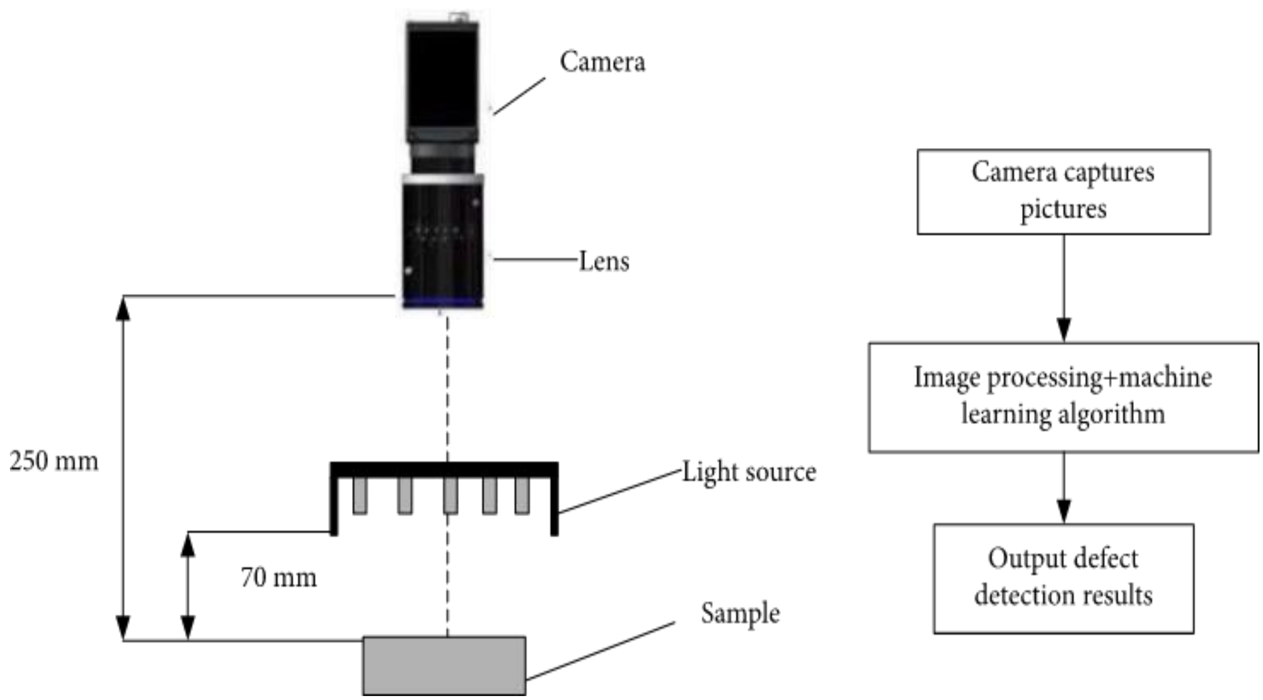


Figure 3. *The flow of constructing a cylindrical panoramic image*

(Source: https://doi.org/10.1155/2022/3719971)

Posture correction methods were also used in the development of 10-12 -year-old karate athletes in terms of physical quantities. The number of athletes with high and medium spinal mobility, the status of their muscular corsets, and their overall performance the number of athletes with high levels of physical fitness has fallen, while the number of athletes with low levels has increased. A static-dynamic exercises set employing the proposed and tested experimental educational technique the athletes' training method had a positive influence on the correction of postural posture defects, according to young karate practitioners. Physical traits and special motor talents of athletes aged 10-12 are developing.

Table 2. Synthesis of Related Studies on Posture-Correction

Author (year)	Title	Relevant Findings	Relation to the Study
Cleveland Clinic (2019) [16]	Back Health and Posture	The health institutions suggest that good posture involves training a person's body when standing, walking, sitting, and lying in positions where the least strain is placed on supporting muscles and ligaments during these activities.	The information in this medical institution website served as a reference for the definition of posture in general.
Choi, K.H., Cho, M.U., Park, C.W., Kim, S.Y., Kim, M.J, Hong, B. Kong, Y. B. (2020) [17]	A Comparison Study of Posture and Fatigue of Neck According to Monitor Types (Moving and Fixed Monitor) by Using Flexion Relaxation Phenomenon (FRP) and Craniovertebral Angle (CVA)	The study assessed the position of the neck and levels of n fatigue by analyzing two specifics: the flexion relaxation phenomenon (FRP) and the craniovertebral angle (CVA).	The study was used as a reference for posture and neck fatigue according to different monitoring types.
Ailneni, R.C., Reddy Syamala, K., Kim, I.-S., & Hwang, J. (2019) [18]	Influence of the wearable posture correction sensor on head and neck posture: Sitting and standing workstations	The results of this research indicate that employing wearable posture sensors in the office environment could be a valuable means of reducing the strain on the neck caused by poor posture.	The study served as a reference for the use of wearable sensors in posture correction.

2.2 Monitoring and Training Systems in Combat Sports and Martial Arts

In posture correction systems in combat sports and martial arts, monitoring, and training systems are usually integrated to properly achieve the goal. Various studies utilize inertial sensors as part of the monitoring and training of a specific sport. Accelerometers and gyroscopes are usually used to provide an accurate 2D orientation of the body. On the other hand, magnetic sensors are added within the IMU to obtain the information for the 3D orientation of the body. With that being said, sensor fusion algorithms are implemented to combine the measured data parameters gathered from the sensors. These parameters are subdivided into three categories which are temporal, kinematic, and dynamic [20].

According to the journals, as cited by Camomilla et al. [20], wearable sensors have been used in coaching systems and provide feedback that is essential in training, these render real-time visual and auditory information that can be analyzed immediately. It is important for these systems to be aligned to the user’s sports-specificity. The system or device should be (1) wearable and lightweight for it to be suitable for training or in-field use, (2) can be set up easily, (3) power-efficient, for long-time monitoring, and lastly (4) provide feedback that is dependable and accessible through a user-friendly interface.

From the studies gathered in [20], 67% use a single sensor configuration which was preferred by the sports, swimming and running, usually inserted through the sports equipment, or attached to the body, specifically, hand or foot. Other studies utilize the sensors by attaching it to the athlete's body using double-sided tapes, straps, Velcro fasteners, elastic stretch bands, or customized vests.

For the activity classification, there are two types, these are unsupervised and supervised approaches. The unsupervised approach uses k-means analysis for the extracted data, with predefined cluster numbers. Nonetheless, a supervised method relies on a dataset with predetermined classifications. Among the classifiers commonly employed in the studies referenced in [20], the notable ones include decision trees, stepwise discriminant analysis of principal components, artificial neural networks (including MLP network and Support Vector Machines), k-nearest neighbor algorithm, Naive Bayesian, and Hidden Markov models.

Echeverria et al. conducted a study that presents a system combining wearable sensors, computer vision, and machine learning to gather motion data with the aim of enhancing the abilities of karate practitioners. There are studies in sports and specifically in Karate that utilize mo-cap type computer vision techniques in analyzing movements and comparing it into a pattern. This study makes use of a mini drone as the visual tracking device, also, it uses inertial sensors such as accelerometer and gyroscope and physiological sensors such as thermometer and pulsometer. The data gathered from these are sent to a web application. Aside from these, it gives auditory feedback through a voice system and visual feedback that can be watched in real-time by the sensei [21].

2.2.1 Monitoring and Training Systems in Taekwondo

Taekwondo has poomsae competitions that heavily rely on the mastery of formation. Taegeuk is one of the sets of Poomsae that is used in building the foundation of teaching Taekwondo. According to the scoring guidelines of World Taekwondo Federation (WTF) as shown in Figure 4, there is a great emphasis on the accuracy and presentation of Taekwondo techniques to master a form or poomsae. As shown in the figure below, accuracy makes up 40% of the scoring criteria whereas the presentation makes up 60% of the scoring criteria [42]. The accuracy depends on the poomsae execution including basic movement and balance and the presentation depends on the speed, power/strength, rhythm, and expression of energy. Aside from these factors, deductions are also made for every technical mistake an athlete makes while performing the formations. The technical mistakes can be minor (i.e., poor balance, incorrect angle of feet, uncoordinated stance, and hand technique, etc.), and major (i.e., incorrect, or omitted movement, clapping or yelling at the wrong movement, unnecessary foot noise in stance, pausing for a long time, etc.) [43][44].

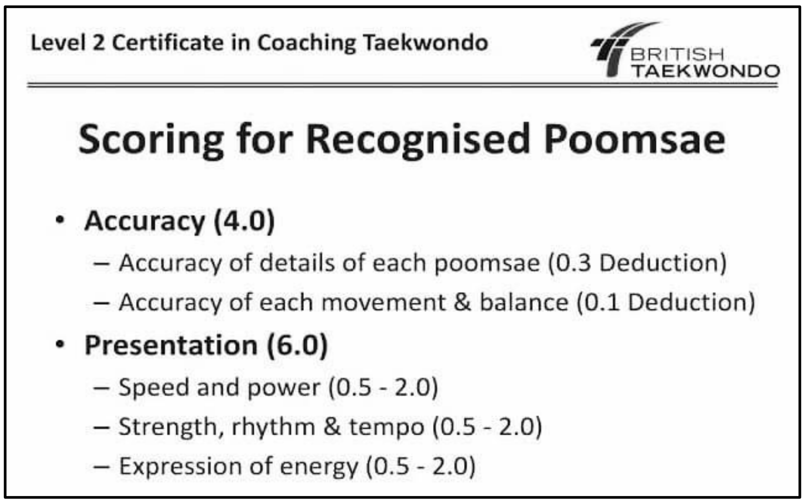


Figure 4. *Poomsae scoring criteria. (D. J. Mella, "Queries about Taekwondo, Importance of Posture in Taegeuk, and Basics about Poomsae," October 08, 2022.)*

With the strict scoring guidelines, the development of a system that assesses the movement of Taekwondo athletes in real-time is essential for their performance [9]. The studies conducted regarding the training and monitoring system of taekwondo athletes utilize motion capture devices such as Inertial Measurement Units (IMUs) and 3D cameras such as Kinect and Orbbec Astra [9, 13, 15, 22, 23]. According to the study conducted by Jang et al., the system demonstrated an improvement in scoring reliability by effectively distinguishing anomalous kicks that pose challenges in judging Taekwondo competitions [13]. Different research assesses the precision of Taekwondo

Poomsae movements by employing motion recognition technology to analyze the motion between an evaluator and a black belt player [15]. According to Cunha et al.'s study, implementing a feedback system to rectify an athlete's techniques enhances their performance within a short timeframe. Furthermore, Rosas-Cervantes et al. propose a real-time system that gauges the power of strikes by collecting data from each strike [22].

2.2.1.1 Static Performance-based Systems

In Taekwondo, the fact that Olympic Poomsae competitions have no quantitative scoring standards caused many fairness issues regarding the scoring done. For this reason, there has been a rise in the need for quantitative evaluation tools. As action recognition is seen as a solution, the extreme movements executed in the sport complicate its application. With this, the Taekwondo Unit technique Human Action Dataset (TUHAD) was established in a study conducted by Lee et al., in 2020. The primary objective of collecting multimodal image sequences of Poomsae actions in this research is to gather data that can facilitate precise vision-based action recognition specifically in the context of Taekwondo [14].

In Dan (Poom) promotion examinations, examiners also usually evaluate the performance of the candidates visually which led to the lack of objectivity in scoring. Regarding this, Choi et al., proposed a Taekwondo Poomsae evaluation system based on motion capture technology to secure the fairness and objectivity of practical evaluation in the said category. The accuracy of the system was checked by comparing the Taekwondo Poomsae motion of the evaluator with the black belt players through the trace of joint regions [13].

Aside from optical motion capture systems, inertial measurement units have also been utilized to evaluate Poomsae's performance. In [24], an innovative approach for the assessment of Poomsae movements was proposed. The results of the study confirmed that the system has the feasibility to become an evaluation tool, increasing the possibility of electronic Poomsae scoring for objectivity purposes.

2.2.1.2 Dynamic Performance-based Systems

Due to the recent advances in technology, the integration of sensors in combat sports systems for the measurement of sports performance and delivery of real-time feedback has been frequently done. As reviewed by Worsey et al., the specific performance feature monitored by most proposed systems is strike quality. Related to this, the head impact caused by Taekwondo kicks was classified by Fifa et al. As the spinning kick worth four points was added to the rules of the sport, the proposed system aimed to warn the medical staff that this type of kick can potentially result in concussion [25].

Taborri et al., citing Saponara, discuss the development of a wireless instrumented plate that can be worn inside an athlete's clothing to measure contact force during martial art sparring sessions. The system was evaluated with Karate athletes, focusing on measuring the contact time and force of strikes. In addition, the authors established two performance metrics, namely kick-strength-to-weight ratio and punch-strength-to-weight ratio and provided feedback to the athletes using a grading scale that ranged from poor to excellent [26]. This feedback allows the athletes to assess their performance based on the strength-to-weight ratios of their kicks and punches.

Accurate score validation and avoiding subjective judgment are some critical limitations observed in Taekwondo competitions. After some accusations of partial judges favoring players, the uncertainty in point validation encouraged the World Taekwondo Federation to adopt the idea of an official electronic body protector (EBP) that allows reliable scoring. After understanding the benefits and limitations of EBP, Rosas-Cervantes et al. developed a prototype that both counts the valid and invalid points as it detects the amount of force of the kicks at the same time. In addition to this, a Human Machine Interface was developed to allow the users to monitor and save their progress after their training [22].

The study described in [13] utilized inertial sensors and a software algorithm to identify and classify anomalous kicks that should not receive scores in Taekwondo competitions. The system monitors the user's joint movement data and the degree of impact when a blow occurs during the match. The researchers proposed the study to contribute to the improvement of scoring reliability as anomalous kicks are considered difficult to judge in competitions.

Ishac et al. conducted a research study that focused on analyzing the velocity, impulse, momentum, and impact force of two specific techniques in Taekwondo: the sine-wave punch and reverse-step punch. The researchers successfully created a non-invasive sensing system that utilizes two action cameras and a single inertial measurement unit to measure the kinematics of martial arts movements. By employing this system, they demonstrated that the main distinction between the two types of punches, the sine-wave punch and reverse-step punch, lies in the potential energy changes of the practitioner's vertical height from the ground during the execution of the techniques [27].

Table 3. Synthesis of Related Studies on Monitoring and Training Systems in Combat Sports

Author (year)	Title	Relevant Findings	Relation to the Study
P. Cunha, P. Barbosa, F. Ferreira, C. Fitas, V. Carvalho, and F. Soares (2021) [9]	Real-time evaluation system for top taekwondo athletes: Project overview	Current methods used in assessing athletes' performance are manuals which led the proponents to develop a low-cost real-time performance evaluation system	The paper was used as a Reference for the combination of Kinect and IMU and the use of CNN and LSTM model.
Jang, W., Lee, K, Lee, W., and Lim, S. (2022) [13]	Development of an Inertial Sensor Module for Categorizing Anomalous Kicks in Taekwondo and Monitoring the Level of Impact	The IMU and software algorithm were developed in identifying the anomalous kicks.	The study was used as a reference for the use of Convolutional Neural Network (CNN).
Lee, J., and Jung, H. (2020) [14]	TUHAD: Taekwondo Unit Technique Human ActionDataset with Key Frame-Based CNN Action Recognition	The keyframe-based CNN architecture was developed specifically for the purpose of recognizing Taekwondo movements.	The collection of multimodal image sequences of Poomsae actions serves the purpose of obtaining data that can be used for precise vision-based action recognition in the context of Taekwondo.

Author (year)	Title	Relevant Findings	Relation to the Study
Choi, C and Joo, H. (2016) [15]	Motion recognition technology based remote Taekwondo Poomsae evaluation system.	The system utilizes motion recognition technology to compare the movements of the evaluator and a black belt player, assessing the accuracy of their motions.	The study was used as a reference for motion capture technology to evaluate Poomsae performance.
Camomilla, V., Bergamini, E., Fantozzi, S., & Vannozzi, G. (2018). [20]	Trends supporting the in-field use of wearable inertial sensors for sport performance evaluation: A systematic review	Studies use inertial sensors as part of the training system. It is also shown that numerous studies use different action classification.	Inertial sensors such as gyroscopes, accelerometers, and magnetometers will be used in this study.
Echeverria, J., & Santos, O. C. (2021). [21]	KUMITRON: Artificial Intelligence System to Monitor Karate Fights that Synchronize Aerial Images with Physiological and Inertial Signals	This study uses inertial and motion capture sensors. In addition, the study also uses a thermometer and pulsimeter. For the visual tracking of the learners, it uses a mini drone as a visual tracking device.	This study proves that the use of motion capture devices in martial arts are feasible.
V. Rosas-Cervantes, R. Salazar, M. Singaña, and F. Silva (2022) [22]	Electronic Training Instrument for Taekwondo Athletes	This paper proposed a prototype to provide a training tool for the monitoring and improvement of Taekwondo techniques	The development of a monitoring system that utilizes Taekwondo performance parameters.
Hailong, L. (2021) [23]	Role of artificial intelligence algorithm for taekwondo teaching effect evaluation model	A study that develops a model that use movement recognition to correct the movements of taekwondo students.	The study improves the teaching mode in Taekwondo.

Author (year)	Title	Relevant Findings	Relation to the Study
Kim, Y. (2021) [24]	New Approach of Evaluating Poomsae Performance with Inertial Measurement Unit Sensors	This study proposed a new method to assess Poomsae performance using inertial sensors through signal processing techniques	The use of inertial measurement units (IMUs) for Taekwondo performance evaluation.
Worsey, M., Espinosa, H., Shepherd, J., & Thiel, D. (2019) [25]	Inertial Sensors for Performance Analysis in Combat Sports: A Systematic Review	Inertial sensors have been integrated into combat sports systems to evaluate performance features and give real-time feedback	Inertial sensors are employed for the analysis of Taekwondo athletes' performance.

2.3 Motion Capturing Sensors

In monitoring and training systems, sensors are needed to be able to classify and properly monitor motion. Motion Capture (MoCap) Sensors are used for such cases, and they can be classified in two ways: Visual Capturing and Inertial Sensors.

Visual Capturing such as Vicon and Kinect is used in the papers compiled. On the other hand, wearable inertial sensors that can be used are IMU and MEMS. Each type of MoCap Process has its own advantages and disadvantages, which is why a Hybrid system, where data fusion of two or more different sensors, was used in some cases.

2.3.1 IMU Sensors

Recent advancements in technology have allowed new ways of training and performance evaluation in sports. For instance, highly miniaturized, low-cost, and power-efficient sensors are integrated into wearable technologies. The use of Inertial Measurement Units (IMUs), or simply, Inertial Sensors, in wearable devices has been relevant. that there is a trend in published papers regarding their use in sports [20, 25, 26].

IMU sensors fall into the Micro-Electro-Mechanical Systems (MEMS) because of their portability, lightweight, affordable cost, efficient power consumption, and many more [26]. MEMS (Micro-Electro-Mechanical Systems) are miniature devices integrated at the chip level, designed to manipulate the inertial motion of silicon-based arms functioning as a mass and a spring. These devices enable the measurement, logging, and transfer of acceleration and rotation data from the body through the utilization of this inertial movement [25].

The Inertial Measurement Unit shown in Figure 5 (IMU) consists of three mutually orthogonal accelerometers, three mutually orthogonal gyroscopes, and usually a three-axis magnetometer [23]. The term "Inertial" is applied to these sensors because they utilize the principle of inertia to gather readings related to velocity, acceleration, and magnetic fields [20]. Each sensor serves a specific purpose in measuring and collecting data concerning the body segment it is worn on. Moreover, the integration of these sensors into a single unit allows for the implementation of robust sensor fusion algorithms, enabling accurate and detailed information to be derived from dynamic situations and various application scenarios [29].

Figure 5. *IMU Unit (Source: http://www.adeept.com/mpu-9250_p0186.html)*

A MEMS gyroscope (Figure 6) is a device that employs silicon as a substrate for micro-level processing. It operates based on the measurement of angular velocity of a vibrating object sensor. MEMS gyroscopes offer several advantages such as low power consumption, affordability, ease of installation, compact size, and suitability for mass production. Consequently, they are commonly found in the low-end market [30]. In terms of performance indicators, the key parameters for gyroscopes in Inertial Measurement Units (IMUs) include measurement range, zero bias stability, and resolution [30].

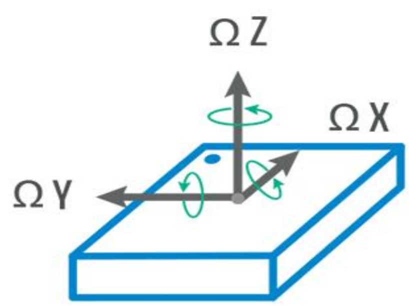


Figure 6. *Gyroscope Sensing - Angular Orientation (Source: https://www.ceva-dsp.com/ourblog/optimize-your-imu-with-dynamic-calibration/)*

Aside from the gyroscope, the MEMS accelerometer (Figure 7) is part of the Inertial Measurement Unit. Accelerometers are utilized to monitor physical activity characteristics and offer valuable insights into joint and body orientations [27]. They are also employed to measure the acceleration of a subject, providing information about their motion and movement patterns [30]. When comparing the two sensors, it is observed that the accelerometer exhibits superior static stability compared to the gyroscope, while the gyroscope demonstrates better dynamic stability [30]. Furthermore, the accelerometer primarily evaluates the modulus value of the XYZ axis, which ideally should be equivalent to the local gravitational acceleration when at rest [30].

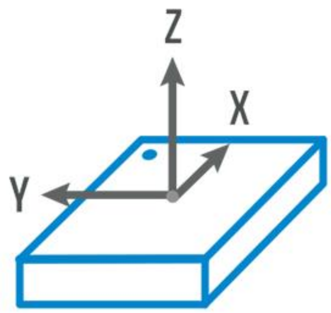


Figure 7. *Accelerometer Sensing - Axis Orientation (Source: https://www.ceva-dsp.com/ourblog/optimize-your-imu-with-dynamic-calibration/)*

Magnetometers are sensors capable of measuring the components of the local magnetic field vector, both around and along their sensing axis (Figure 8) [20]. Like accelerometers, magnetometers also measure the modulus of its XYZ axis, however, its data is easily troubled by the device surrounding magnetic field [30].

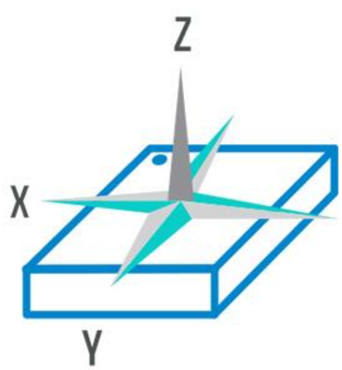


Figure 8. *Magnetometer Sensing - Axis Orientation (Source: https://www.ceva-dsp.com/ourblog/optimize-your-imu-with-dynamic-calibration/)*

The combination of the sensors, gyroscope, accelerometer, and magnetometer, makes the IMU suitable for the measurement and analysis of a body or an object's posture [30]. Overall, the inertial sensors work efficiently and reliably by detecting the rate of acceleration, changes in rotational attributes (i.e., pitch, roll, yaw), and orientation around the gravity vector. All the data are measured relative to a global Inertial Measurement Unit (IMU) coordinate system, then transmitted to a computer where they undergo mathematical processing using computational algorithms [9, 20, 25].

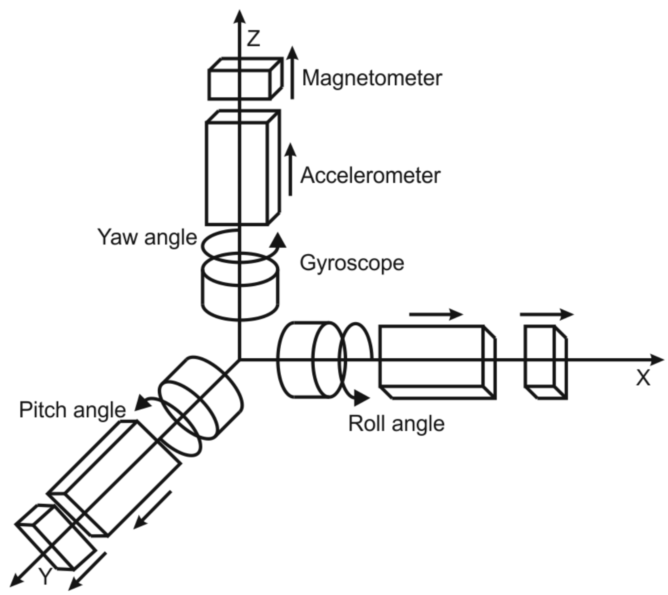


Figure 9. *IMU Coordinate System*

(Source:https://www.researchgate.net/publication/322668267_Concept_of_AHRS_Algorithm_Designed_for_Platform_Independent_Imu_Attitude_Alignment)

2.3.2 3D MoCap Sensors

Another type of sensor used in motion capture systems are 3D MoCap Sensors that are based on visual data. Three-dimensional (3D) motion capture systems are widely utilized and accurate, although they are expensive and not readily available in clinical settings. In a study that compares the ability of Microsoft Kinect (Figure 10) and Vicon 3D motion for human motion or locomotion [40]. This was to compare Kinect with Brekel Kinect software to the Vicon Nexus during sagittal plane gait kinematics to see how well they worked together. The correlation between Kinect and Vicon hip angular displacement was extremely poor, and the inaccuracy was considerable. Kinect knee measurements were better than hip measurements, but not consistent enough for clinical use. The correlation between Kinect and Vicon stride timing was high, with a slight inaccuracy. The slowest velocity had the least variation in Kinect measurements. The Kinect has basic motion capture capabilities and will be an acceptable tool for measuring stride time with some minor tweaks, but extensive developments in software and hardware are required to improve Kinect sensitivity before it can be used in clinical settings [40].

Figure 10. *Microsoft Kinect (Source: eBay PH)*

2.3.3 Hybrid Systems using IMU and Camera MoCaps

Research proves that motion capture cameras and inertial sensors can accurately identify the movement created by the player. A study analyzes posture data using IMU sensor modules to carefully determine the anomalous kicks that occur during Taekwondo matches [13]. According to Kwon as cited by Jang et al., a system was developed, which is composed of a visual sensor, body sensor, and a display device, to detect and evaluate the Taekwondo motions. Real-time images were acquired through the camera and the visualized body sensor data. The purpose of this is to compare the motion created to the template motion that was performed and analyze the difference in both performances. In line with this the study focused on single motions, which helps in improving static postures and dynamic gestures of athletes [13, 38].

Studies have led to the confirmation that Kinect cameras are efficient in recognizing human body movements. However, there are instances that cameras could not properly capture the movements due to rotation or overlapping of an athletes' limbs which encouraged the use of inertial measurement units (IMUs) as additional sensors for the limbs' displacement and acceleration. With the continuous demand for intelligent monitoring systems to monitor biological functions, sports performance improvement, among others; more research that proposes systems using the combination of IMUs and cameras has been conducted [9,31].

According to the study of Milosevic et al, researchers proved that combining the Kinect and a set of wearable IMU systems achieves higher accuracy than any of the two. Studies had analyzed and validated the performance of the combined system, i.e., IMUs and Kinect, in clinical applications of human tracking motion, which includes the postural and balance control [29].

In [9], the researchers proposed a system that utilizes the 3D Camera Orbbec Astra and inertial measurement units to enable the real-time assessment of the performance of Taekwondo athletes during their training sessions. The optical motion capture system is in charge of gathering and displaying the data related to the athlete's hand and feet, including acceleration, speed, and applied force. Meanwhile, the IMUs track and measure the movement and acceleration of the athlete's upper and lower limbs.

In a study about motion capture algorithm conducted in 2021, a lower limb joint 3D position estimation algorithm was suggested by using data accumulated from both the inertial sensors and Kinect. Errors caused by accelerated movements and magnetic distortions were compensated using the IMUs while the data obtained from the Kinect was used as reference points for estimation improvement [23].

Yang et al. also presented the IMU-Kinect system to remotely monitor gait rehabilitation. The IMUs attached on the lower limbs made it possible to estimate the rotation and displacement of the thighs and shanks. This data was then combined with the geometric models of human lower limbs to estimate the gait parameters. By placing markers on the sensors' surfaces, the Optitrack system was used to capture the ground truth for the evaluation of the proposed system [32].

Table 4. Synthesis of Related Studies on Motion Capturing Sensors

Author (year)	Title	Relevant Findings	Relation to the study
P. Cunha, P. Barbosa, F. Ferreira, C. Fitas, V. Carvalho, and F. Soares (2021) [9]	Real-time evaluation system for top taekwondo athletes: Project overview	Current methods used in assessing athletes' performance are manuals which led the proponents to develop a low-cost real-time performance evaluation system	The paper was used as a Reference for the combination of Kinect and IMU and the use of CNN and LSTM model.
Camomilla, V., Bergamini, E., Fantozzi, S., and Vannozzi, G. (2018) [20]	Trends Supporting the In-Field Use of Wearable Inertial Sensors for Sport Performance Evaluation: A Systematic Review	Studies use inertial sensors as part of the training system. It is also shown that numerous studies use different action classification, these are unsupervised and supervised approach.	The paper was used as a reference for the Inertial Sensors and how they are being used in Sports Performance Evaluation.

Author (year)	Title	Relevant Findings	Relation to the study
Worsey, M., Espinosa, H., Shepherd, J., & Thiel, D. (2019) [25]	Inertial Sensors for Performance Analysis in Combat Sports: A Systematic Review	This review provides a concise framework for effectively selecting and implementing inertial sensor technology in the evaluation of combat sports performance.	The use of inertial sensors for the analysis of Taekwondo athletes' performance
Taborri J, Keogh J, Kos A, Santuz A, Umek A, Urbanczyk C, Van Der Kruk E, Rossi S. (2020) [26]	Sport Biomechanics Applications Using Inertial, Force, and EMG Sensors: A Literature Overview	Based on the findings of the literature review, it was determined that inertial sensors are the most commonly used sensors in evaluating athletes' performance.	The paper was used as a reference for the Inertial, Force, and EMG Sensors, how they generate data, how to process their data, and where they can be applied.
Mendes, J. J. A., Vieira, M. E. M., Pires, M. B., Stevan, S. L. (2016). [31]	Sensor fusion and smart sensor in sports and biomedical applications	The results of this study confirm that the use of IMU and Kinect as a combination for sports and biomedical applications is very apparent.	The paper served as a reference for the use of Inertial and Kinect Sensors Sports and Biomedical Applications.
Yang, P., Xie, L., Wang, C., Lu, S. (2019). [32]	Demo: IMU-Kinect: A Motion Sensor-based Gait Monitoring System for Intelligent Healthcare.	The wearable IMU-Kinect system monitors the rehabilitation of lower limbs	The paper was used as an additional reference for IMU and Kinect Sensors.
Kwon, D. Y. (2013). [38]	A Study on Taekwondo Training System using Hybrid Sensing Technique	The study successfully built a taekwondo training system combining body and visual sensor data using real-time motion analysis and Hidden Markov Models.	The paper served as a reference for the integration of hybrid sensing into a training system.

Author (year)	Title	Relevant Findings	Relation to the study
Ishac, K., Eager, D. (2021) [27]	Evaluating Martial Arts Punching Kinematics Using a Vision and Inertial Sensing System	This paper examined the velocity, impulse, momentum, and impact force of the Taekwondo sine-wave punch and reverse-step punch.	The paper was used as a reference for Hybrid Sensing and usage of motion analysis software.
Abbasi, J., Salarieh, H., Alasty, A. (2021) [28]	A motion capture algorithm based on inertia-Kinect sensors for lower body elements and step length estimation	Kinect and IMU sensors are being considered for their efficiency, however, these devices encounter problems. As a result, the authors did an improvement in 3D position estimation and step length estimation.	The paper was used as a reference for data fusion.
Milosevic, B., Leardini, A., Farella, E. (2020). [29]	Kinect and wearable inertial sensors for motor rehabilitation programs at home: State of the art and an experimental comparison.	This study proves that the combined system of Kinect and IMU's provides a higher accuracy compared to one of the two devices.	The paper served as a reference for the use of Inertial and Kinect Sensors in Human Motion Tracking.
S. Li, C. Liu, and G. Yuan (2021) [30]	Martial Arts Training Prediction Model Based on Big Data and MEMS Sensors	The utilization of IMU addresses the challenge of inadequate testing accuracy of optical motion capture systems in low-light conditions and situations where motion is obstructed.	The paper was used as a reference for IMU sensors.

2.4 System Algorithms and Data Analysis Techniques

For each type of system used and what output should be processed, different algorithms and data analysis techniques were used. Hybrid MoCap systems may cause some problems in the system (due to the differences in the dimensions of the raw data of different sensors) which is why the fusion process should also be focused on. Additionally, there will be a significant difference in the system algorithms and models used when the output expected is given in real-time and not.

2.4.1 Data from the Sensors

The emergence of MEMS technology has allowed researchers to use IMUs in measuring biomechanical patterns during in-sport movements, providing valuable information about movement quality for performance and injury prevention [33]. Furthermore, this enables researchers to measure both the static and dynamic states of an athlete's body. In the static state, crucial parameters include spatial position, orientation, posture, and angles between body parts. In the other hand, important parameters encompass displacement, trajectory, velocity, linear acceleration, jerk, angular velocity, and angular acceleration. [26].

In addition to the static and dynamic states, IMUs have three kinds of sensor-derived metrics, these are temporal, kinematic, and dynamic. Detecting characteristics (e.g., minima, maxima, or slope shifts) in observed acceleration signals or angular velocity angular velocity or is a common way to extract temporal parameters. Position, velocity, and acceleration in both angular and linear versions are referred to as kinematic parameters. Lastly, dynamic parameters, like kinematic quantities, refer to both angular and linear variables [20].

In a study about movement recognition and correction done in 2021, Hailong considered various posture changes in human movements, where key parameters are speed, displacement, acceleration, and angle changes of nodes of the human body. In his study, speed is a vector that considers movement direction, and acceleration is also a vector that incorporates both horizontal and vertical changes in speed. Additionally, the angular velocity involves data from both knee and elbow joints. These key parameters were laid out in a 3D coordinate system and run through analyzing software [23].

Besides the IMUs, the researchers of this project study plan to use a visual sensor, specifically a Kinect sensor because of its low acquisition value, portability, marker less sensing, ease of use, and 3D imaging ability. Since Kinect is a 3D video motion system, researchers can use it for human movement kinematics analysis of body joints and segments in several areas [9].

In a study about a real-time evaluation system for Taekwondo athletes, the authors used visual cameras to collect human body movement data. These data underwent data mining classification methods in video streaming of twenty body-joints positions of the human body [9]. In their study, the 3D camera and visual system provided real-time the athlete's hands and feet joints movements data in Cartesian coordinates numeric values, Cartesian coordinates line chart, and speed line chart [9].

All data parameters coming from the IMU and Kinect Sensors must be fused for them to be processed generally and used to achieve the other goals of the study. Fusion algorithms and techniques are further discussed in the following subtopics.

2.4.2 Data Fusion Techniques

Data fusion is a significant step for researchers to achieve their goal of actively monitoring and correcting an athlete's posture using IMU and Kinect Sensors. Several types of research prove that data from body sensors like IMUs and visual sensors like Kinect have been successfully combined for pose estimation and human activity recognition [34]. Human pose estimation relies on extracting and merging the body's skeletal key points and joint locations to create a two- or three-dimensional human body structure.

A motion-sensing Kinect Sensor consists of three major components: a multi-array microphone, a color VGA video camera, and depth sensors. The depth sensor is made with an infrared projector and a monochrome complementary metal-oxide-semiconductor sensor. The color camera gathers red, green, and black image data used for facial recognition and other detection features. These two features work together to directly fetch the depth of users in X, Y, and Z positions regardless of the lighting condition. Lastly, microphones allow users to control a computer with human voice commands [35]. Like Kinect, IMUs consist of three sub-sensors like gyroscopes, accelerometers, and magnetometers. These IMUs are placed on different body segments to capture numerical measurements vital for pose estimation.

For the researchers to use the raw data produced by the components of the Kinect sensors, several features must be extracted from each image or frame [34]. Additionally, to use the features, and their associated points for pose estimation, a model is required to relate the points in the image to its environment [34]. On the other hand, a fusion algorithm and a smoothing or filtering approach are required to use raw data from IMU sensors [34].

One of the models that the researchers of this study can use is the simple kinematic model as presented in the study by M. Trumble, A. Gilbert, C. Maileson, et al [36]. There they used Temporal Sequence Prediction (TSP) on videos and IMU to provide contextual frame-wise predictions using Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM) layers. This methodology from their study produced a highly accurate result for pose estimation [36].

Another model or network architecture that can be adapted to this study is the data fusion done in the study conducted by F. Huang, A. Zeng, M. Liu, Q. Lai, & Q. Xu [10]. Here, the LSTM was trained to map the previous camera pose and subsequent inertial measurements to the next camera pose. The study also incorporated a linear Kalman filter to fuse the inertial tracking pose estimation with visual pose estimation. This approach resulted in a robust final pose estimate that accounted for challenges such as fast motion blurring, occlusions, and changes in illumination. Additional filtering and smoothing were used to optimize the raw data coming from the IMUs. Smoothing was used for all data from time = 1, …, N, and filtering was used for the data up to a particular time t to estimate the position and orientation at time t [34].

In the UTD-MHAD dataset [11] and CZU-MHAD dataset [47], where both Kinect Sensor and inertial sensors were used, two vital processes called data synchronization and annotation through visual inspection were mentioned. With these processes, the frame rate of the Kinect camera and the sampling rate of the wearable devices can be synchronized in terms of their time stamps. Aside from the synchronization, these studies were able to make use of existing statistical approaches to clean out the noises and artifacts in their datasets. A multi-modal fusion approach (e.g., transforming visual data into depth motion maps to arrays and fusing it to the numerical data from the inertial sensors) that combined both the data from the camera and inertial sensors was used in these studies to generate a unique feature per movement.

The data fusion algorithms and techniques stated in this part of the review are vital for the data gathering and benchmarking of the researchers. Fused data will need to undergo a Deep Learning method, discussed in the following subtopic.

2.4.3 Machine Learning Model

From the RRLs compiled for the study, the Machine Learning Algorithms used in systems for monitoring and motion recognition can be grouped into two ways: Real-time Monitoring and Non-Real-Time Monitoring.

Non-real-time monitoring systems used classifier models such as SVM, Naïve Bayes, and Decision Tree; with most leaning toward SVM. SVM is a two-class classification system that classifies information using linear regression by mapping high-dimensional data to linear space. This is because SVM is the model usually used for processing high-dimensional data [23,30].

In a study that uses MEMS sensors, SVM is used for training and injury risk prediction models. It uses MEMS to predict the motion of the user and uses this data to classify the said motion. The idea of using SVM is to find the best hyperplane in space to be able to separate the positive and negative samples. It was also compared to Logistic Regression and Naive Bayes in this study, this may be due to the higher accuracy these two systems showed in motion recognition when Kinect was used [15]. However, through the higher AUC and lower time it takes to process the data in this study, SVM is deemed better than the two. The limitation of this study, however, is that it only uses inertial sensors and forms only the lower limb of the human body [30]. In another study, SVM is used to recognize the movement characteristics of the students to be able to correct these movements and guide them.

Since this study will attempt to focus on instant feedback monitoring, the proponents will be using CNN models with added additional algorithms and filters to fulfill the disadvantages of CNN.

In a study conducted by Cunha et all. which uses IMU sensors and a 3D Camera to collect data on the movement of the body during training, the CNN+LSTM deep learning model achieved the best results by having 93% accuracy in real-time detection of the motion of the person [9]. This model uses the CNN layers for feature extraction and the LSTM is added to support the sequence prediction [39].

A study by Jang et al. uses Adaptive Moment Estimation (ADAM) based on gradient descent as an optimizer to categorize an anomalous kick from an anomalous kick using an IMU sensor module in the shoes of the athlete. ADAM is another type of CNN under the Keras sequential model [13]. On the other hand, another paper combined CNN classifiers and applied some ADAM optimizers in their study [14]. CNN was used for feature extraction and ADAM optimizers were applied to train the parameters.

A study in 2020 utilized the UTD-MHAD and Berkeley-MHAD to create a Multi-Modal Human Action Recognition (HAR) Model [12]. The developers created a total of five CNN and LSTM models for the angle-velocity feature, angle feature, optical feature, still image, and signal diagram from the inertial sensors. These five models were combined to create an ensemble or a fully connected layer. The final model has been trained on 60 percent of the dataset. The remaining 40 percent was divided equally for model testing and validation. The overall accuracy of the created multi-modal action recognition algorithm was found to be 0.991 for UTD-MHAD and 0.996 for Berkeley-MHAD.

On the other hand, another paper uses another type of CNN model for human recognition. It uses the Lightweight Neural Network, specifically, YOLOv3 for motion recognition and Taekwondo training. The data used in this study is that of video surveillance and IMU sensors [37].

The algorithms and techniques in the studies are essential for the formulation and development of the deep learning model used by the researchers of this paper.

Table 5. Synthesis of Related Studies on Monitoring System Algorithms and Data Analysis Techniques

Author (year)	Title	Relevant Findings	Relation to the Study
P. Cunha, P. Barbosa, F. Ferreira, C. Fitas, V. Carvalho, and F. Soares (2021) [9]	Real-time evaluation system for top taekwondo athletes: Project overview	Current methods used in assessing athletes' performance are manuals which led the proponents to develop a low-cost real-time performance evaluation system	The paper was used as a Reference for the combination of Kinect and IMU and the use of CNN and LSTM model.

Author (year)	Title	Relevant Findings	Relation to the Study
F. Huang, A. Zeng, M. Liu, Q. Lai, & Q. X (2020) [10]	DeepFuse: An IMU Aware Network for Real-Time 3D Human Pose Estimation from Multi-View Image(g)	The effectiveness of data fusion and algorithms used in this study is proven.	The paper was used as a reference for the usage and efficiency of using the LSTM model human pose estimation.
Chen, C., Jafari, R., & Kehtarnavaz, N. (2015) [11]	UTD-MHAD: A multimodal dataset for human action recognition utilizing a depth camera and a wearable inertial sensor.	In this study, the UTD-MHAD dataset is utilized for human action recognition.	The paper was used as a reference for the utilization of fusion techniques and data synchronization.
Choi, C and Joo, H. (2016) [15]	Motion recognition technology based remote Taekwondo Poomsae evaluation system.	The technology identifies Taekwondo Poomsae motion by analyzing the trajectory of specific joint areas.	The use of motion capture technology to evaluate Poomsae performance.
Camomilla, V., Bergamini, E., Fantozzi, S., and Vannozzi, G. (2018) [20]	Trends Supporting the In-Field Use of Wearable Inertial Sensors for Sports Performance Evaluation: A Systematic Review	Its effectiveness is further enhanced when incorporated into a sensor fusion network.	The paper was used as a reference for the sensor-derived metrics namely, temporal, kinematic, and dynamic.
Hailong, L. (2021) [23]	Role of artificial intelligence algorithm for taekwondo teaching effect evaluation model	The findings of this research demonstrate the efficacy of the proposed model presented in this paper, indicating its applicability in teaching practice.	The paper was used as a Machine Learning Reference specifically for Support Vector Machines. It was also used for the output produced by the motion camera.
Taborri J. Keogh J, Kos A, Santuz A, Umek A, Urbanczyk C, Van Der Kruk E, Rossi S. (202	Sport Biomechanics Applications Using Inertial, Force, and EMG Sensors: A Literature Overview	It was determined that inertial sensors are the most used sensors in evaluating athletes' performance.	The paper was used as a reference for the dynamic and static states of an athlete's body.

Author (year)	Title	Relevant Findings	Relation to the Study
Jang, W., Lee, K, Lee, W., and Lim, S. (2022) [13]	Development of an Inertial Sensor Module for Categorizing Anomalous Kicks in Taekwondo and Monitoring the Level of Impact	The IMU and software algorithm were developed in identifying the anomalous kicks.	The use of Convolutional Neural Network (CNN)
Lee, J., and Jung, H. (2020) [14]	TUHAD: Taekwondo Unit Technique Human ActionDataset with Key Frame-Based CNN Action Recognition	The keyframe-based CNN architecture was developed specifically for the purpose of recognizing Taekwondo movements.	Multimodal image sequences of Poomsae actions collected aims to enable precision vision-based action recognition and provide data in Taekwondo
S. Li, C. Liu, and G. Yuan (2021) [30]	Martial Arts Training Prediction Model Based on Big Data and MEMS Sensors	The support vector regression model effectively identifies and utilizes crucial samples as support vectors, enhancing its robustness.	The paper was used as a reference for the usage and efficiency of using the SVR model for Big Data and MEMS Sensors.
Alanen, A., Raisanen, A., Benson, L., Pasanen, K. (2021) [33]	The use of inertial measurement units for analyzing change of direction movement in sports: A scoping review	From the study's findings, change of direction (COD) motions and COD heading angles can be detected with satisfactory validity using inertial measurement units (IMU), but IMU measured or derived kinetic or kinematic variables have inconsistency and overestimation.	The paper was used for assessment of the reliability and validity of inertial measurement unit sensors (IMUs) in providing biomechanical patterns in sports evaluation.

Author (year)	Title	Relevant Findings	Relation to the Study
Kok, M., Hol, J., Schön, T. (2017) [34]	Using inertial sensors for position and orientation estimation	The main emphasis of this research is on the signal processing components related to the estimation of position and orientation using inertial sensors. It explores various modeling options and highlights a few significant algorithms.	The paper was used as a reference for the usage of inertial sensors and motion capture cameras. Aside from that, it was used as a guide for data extraction, data fusion, and data filtering/smoothing.
Lun. R. (2018) [35]	Human Activity Tracking and Recognition Using Kinect Sensor	The objective of this research was to create a comprehensive application that leverages the Kinect sensor, a motion sensing input device, to track non-compliant postures of consenting healthcare workers. as adaptive boost..	The paper was used as a reference for the usage of Kinect sensors in identifying human movements and activities. It was also used as an additional reference for the specific outputs and components in the Kinect sensor.
M. Trumble, A. Gilbert, C. Maileson et al (2017) [36]	TOTAL CAPTURE: POSE ESTIMATION FUSING VIDEO AND IMU DATA Total Capture: 3D Human Pose Estimation Fusing Video and Inertial Sensors	In this paper, a new algorithm was introduced for accurately estimating the 3D pose of human beings. This algorithm combined video signals (MVV) and inertial signals (IMU) to achieve a high level of precision in pose estimation.	The paper was used as a reference for the usage and efficiency of using the LSTM model for temporal pose estimation.

CHAPTER 3

METHODOLOGY

Chapter 3 features the methodology. This includes how the research was conducted, which includes Research Design, Research Process Flow, Analysis, and Project Work Plan.

3.1 Research Design

This study aimed to develop a posture detection and monitoring system that focused on Taekwondo Poomsae Training by creating a device that detected the trainee's performance and provided feedback, which helped in improving the trainee's performance. Figure 11 summarizes the input parameters, objectives, processes done, and the expected output of the system.

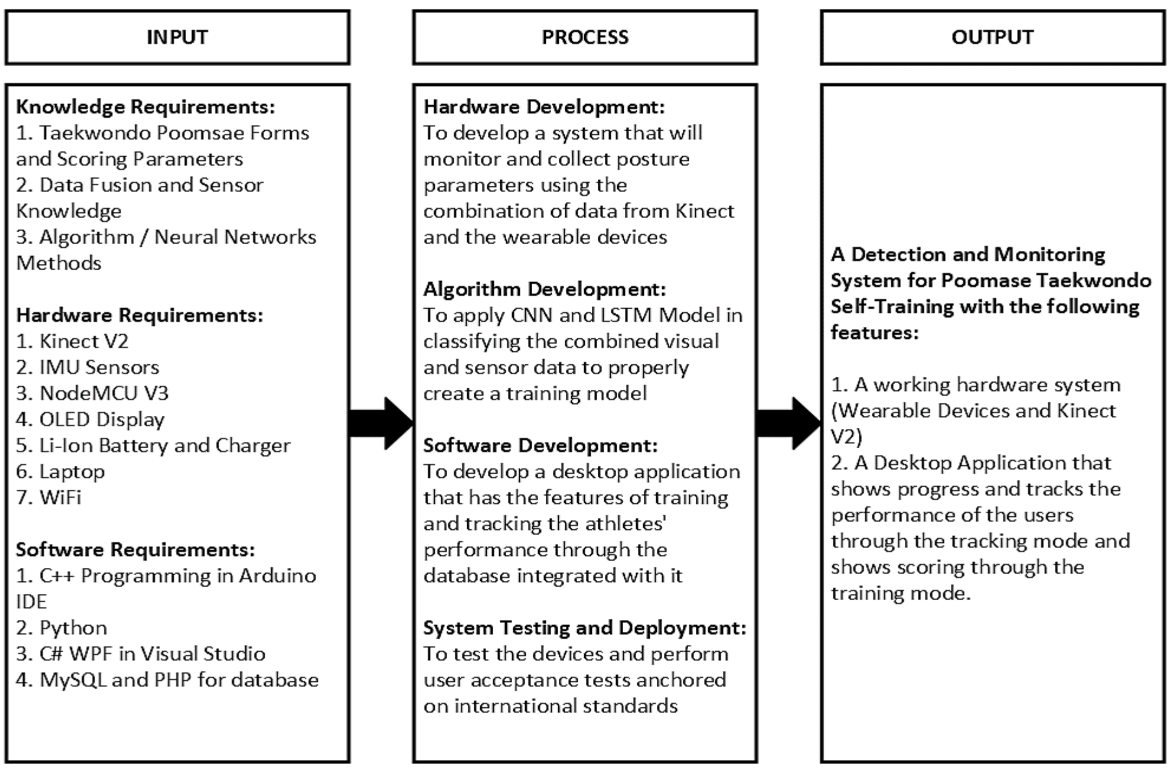


Figure 11. *IPO Diagram of the Study*

This study is under developmental research that showed the systematic study of posture in Poomsae sport. Developmental study is defined as a systematic study focused on meeting the criteria of consistency and effectiveness through designing, developing, and evaluating programs and projects. This study explored the correct posture in performing Poomsae using Kinect and IMU sensors that were used to conduct this study. The descriptive study was also explored as the environment was changed in which data and information were gathered to identify the relative effects of the device on the competence of the athletes in this sport.

3.2 Research Process Flow

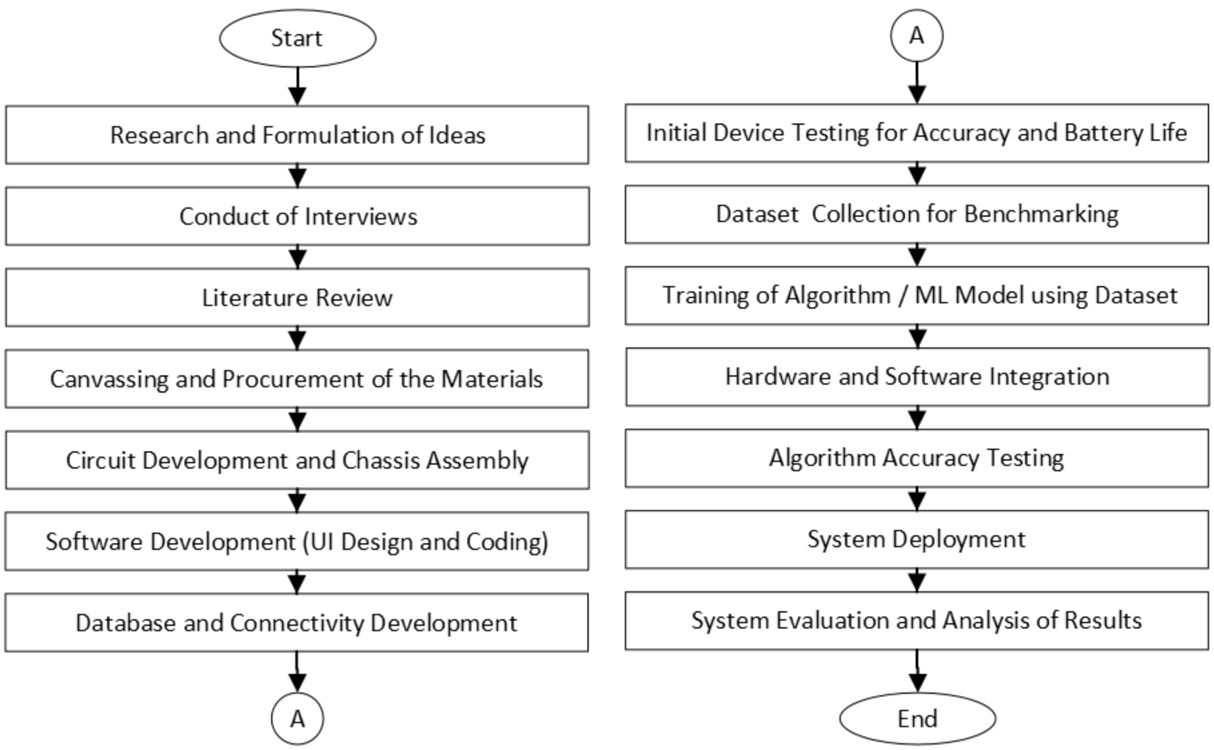


Figure 12. *Research Process Flow of the Study*

The figure above (Figure 12) represents the process flow and the major steps needed to complete this project. The study started with identifying the problem, researching related studies, and formulating ideas for solving the problem. A series of interviews were conducted with professional Taekwondo athletes and coaches and verified the correctness of the study's direction and foundational information.

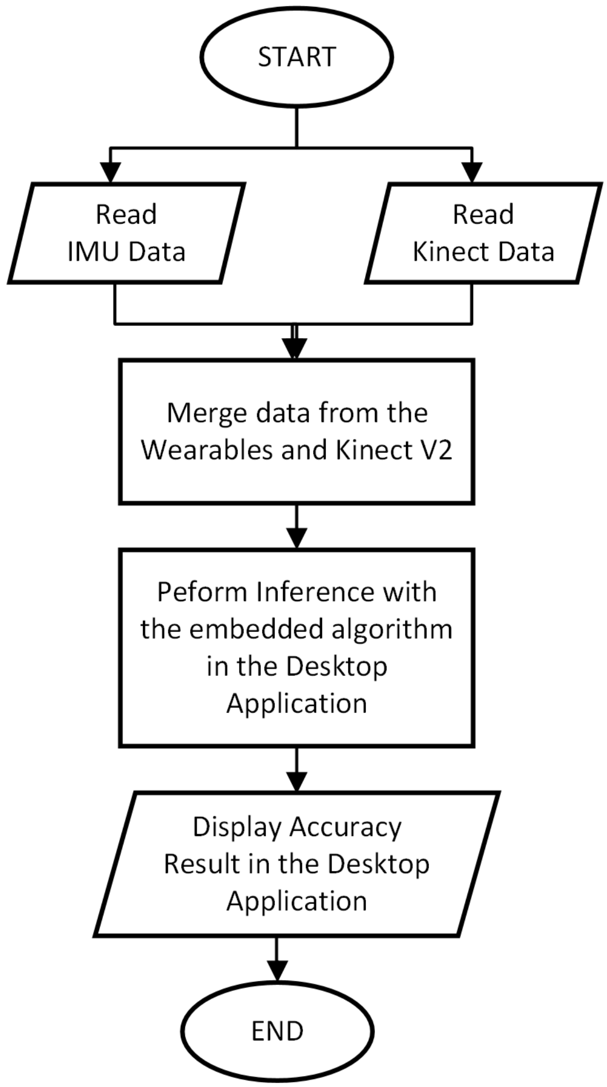


Figure 13. *Flowchart of the system*

The canvassing and procurement of materials were done after the literature review and conduct of interviews. After this came the development of hardware and software, which consisted of circuit development, chassis designing, UI/UX designing, programming, and database establishment. After the creation of the hardware and initial software came the initial testing to check the performance and accuracy of the system. Figure 13 shows the overview of the system's process.

The researchers also partnered with TUP - Manila's Taekwondo Team for the Poomsae Dataset Creation. The study utilized the gathered dataset for data fusion to train the model. After this, the trained model on benchmarked parameters was integrated into the desktop application for actual testing and deployment. Lastly, the researchers conducted User Acceptance Tests and other surveys for feedback purposes.

3.3 Development of Posture Monitoring Device using Kinect and IMU Sensors

The posture monitoring device, which was composed of Kinect and wearables such as IMU sensors, was used to detect parameters such as the acceleration/velocity, angles, orientation, depth data, IR data, calibration data, sensor telemetry, body frame, body index, opaque data, and long exposure IR data.

3.3.1 Gathering of the materials and components that will be used for the posture monitoring devices

The materials needed to set up the wearable device and sensor camera setup were purchased online and through Electronics Retail Stores in the Philippines. Each component was evaluated first before the actual construction to verify if they were all working properly. The following table shows the list of components required for the construction of the hardware devices.

Table 6. List and Billing of Materials

Component	Price per Unit x Quantity	Total Price
GY-91 IMU	445 PHP x 5 PCS	2,225 PHP
Kinect Xbox One w/ Adapter	5,000 PHP x 1 PC	5,000 PHP
Vibration Motor Module	77 PHP x 5 PCS	385 PHP
NodeMCU V3 ESP8266 12E Development Board	160 PHP x 5 PCS	800 PHP
Lithium Ion Battery	200 PHP x 5 PCS	1,000 PHP
18650 Type C Lithium-Ion Battery Charger	30 PHP x 5 PCS	150 PHP
OLED Display Module 12C Interface (0.91 Inch)	150 PHP x 5 PCS	750 PHP
Pololu 5V Voltage Regulator	300 PHP x 5 PCS	1,500 PHP
SPDT Slide Switch	55 PHP x 1 Pack	55 PHP
Solid and Stranded Wires	314 PHP x 1 Set	314 PHP
Filament	850 PHP x 1 Roll	850 PHP
3D Printing	300 PHP x 5 PCS	1,500 PHP
Buckles and Straps	195 PHP x 1 Set	195 PHP
Screws	178 PHP x 1 Set	178 PHP
Tripod Stand for Kinect	1,650 PHP x 1 Set	1,650 PHP

3.3.2 Construction and placement of the wearable device

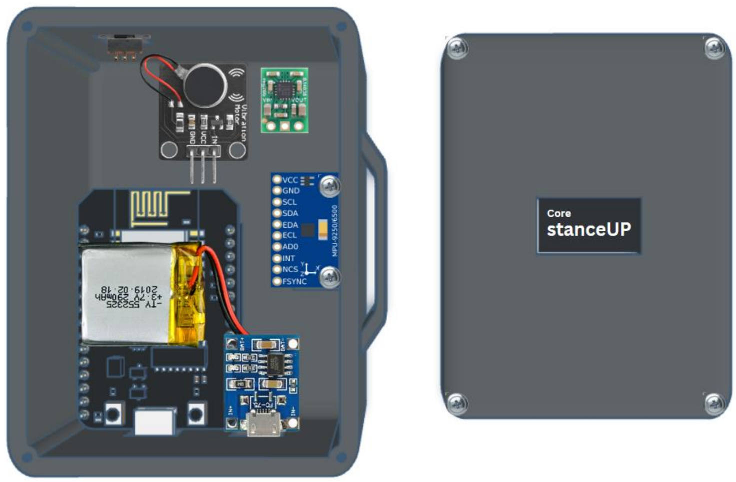


Figure 14. *Hardware Design*

Figure 14 shows the placement of the components inside the 80mm x 60mm wearable device. For durability and safety purposes, each chassis was 3D printed using PETG filament. The GY-91 sensor in each wearable device is elevated and properly secured so that the placement of the sensor will not be affected by the force in the movements of the users. Lastly, the wearables also have 0.91” OLED Displays to indicate the proper placement of each device on the user’s body.

Figure 15. *Placement of Wearable Devices*

Figure 15 shows the proper placement of the wearables on a user's body. Each device should be placed on the wrists, above the ankles, and core/torso. This placement was decided as the mentioned parts were considered the most important in a Taekwondo athlete's body, as stated and verified by Coach Gilbert Dominic Balajadia, one of the Taekwondo coaches at the Technological University of the Philippines-Manila, and Coach Dustin Jacob Mella of the Philippine Taekwondo Association [6].

3.3.3 Calibration of the IMU and determining the parameters that should be measured

The wearable device had to be calibrated to determine the proper parameters to be measured. It also had to be set up with Kinect and wireless Wi-Fi to ensure the transmission of information obtained from each device.

3.4 Development of Desktop Application for Training and Tracking Athletes' Performance through the database that stores the user's data and other vital parameters

The desktop application served as the interface of the data for the athletes' performance during the training sessions. The monitoring system worked by gathering data sets coming from professional Taekwondo athletes and its users. These contained the set of parameters that were used to analyze and assess the system's overall efficiency.

3.4.1 Plan and Define the contents and core features that the application should have

The application featured the training mode, which showed the information about the Taegeuk levels and proper execution of Poomsae techniques. It also featured the tracking mode, which accumulated the scores of performances per training session.

The front-end design of the developed desktop application can be seen on Chapter 4 (Figures 25-31).

3.4.2 Choose a software development platform and sketch the Design to Build an App Wireframe

After defining and finalizing the features of the desktop application, choosing the right software development platform was vital. The project used Visual Studio as its official coding and development platform. Using this platform, the wireframe and design of the user interface were made over a span of one month.

3.4.3 Code the functionalities and connect the outside information through the code

To complete the desktop application, coding through the programming language C# WPF in Visual Studio was needed. The coding helped the researchers build the features and functionalities of the software. The last vital step to achieving the objective of this project was to establish a connection between the software and hardware devices.

3.4.4 Create a Database System for Storing User Data and Other Vital Parameters

For the monitoring and detection system to work, it needed datasets coming from professional Taekwondo athletes and users. These datasets contained the set of parameters that would be used to analyze and assess the system's overall efficiency. The set of parameters can be found on Tables 7 and 8.

Table 7. IMU Parameters for Data Gathering

Data Subject __ Movement __ Taegeuk Level __							
Wearable Device	**Gx**	**Gy**	**Gz**	**Ax**	**Ay**	**Az**	**Orientation**
Right Foot							
Right Arm							
Left Foot							
Left Arm							
Core							

Table 8. Kinect Parameters for Data Gathering

Data Subject __ Movement __ Taegeuk Level __							
Depth	**IR**	**Calibration Data**	**Sensor Telemetry**	**Body Frame**	**Body Index**	**Opaque Data**	**Long Exposure IR**
File Name: ______________________________				Time Stamp: __________ - __________			

3.4.5 Setting up the Database System

The database was not hosted online but instead was hosted locally through the users' devices and personal computers. It was hosted locally because the usage of a third-party database system provider might have affected the connectivity and storage of the hardware devices. For the Kinect V2 sensor, the local disk was used as a storage device (Figure 17). Meanwhile, a separate database through MySQL was used for the wearable devices since the sensors provided numerical data that should be stored in a tabular manner (Figure 16).

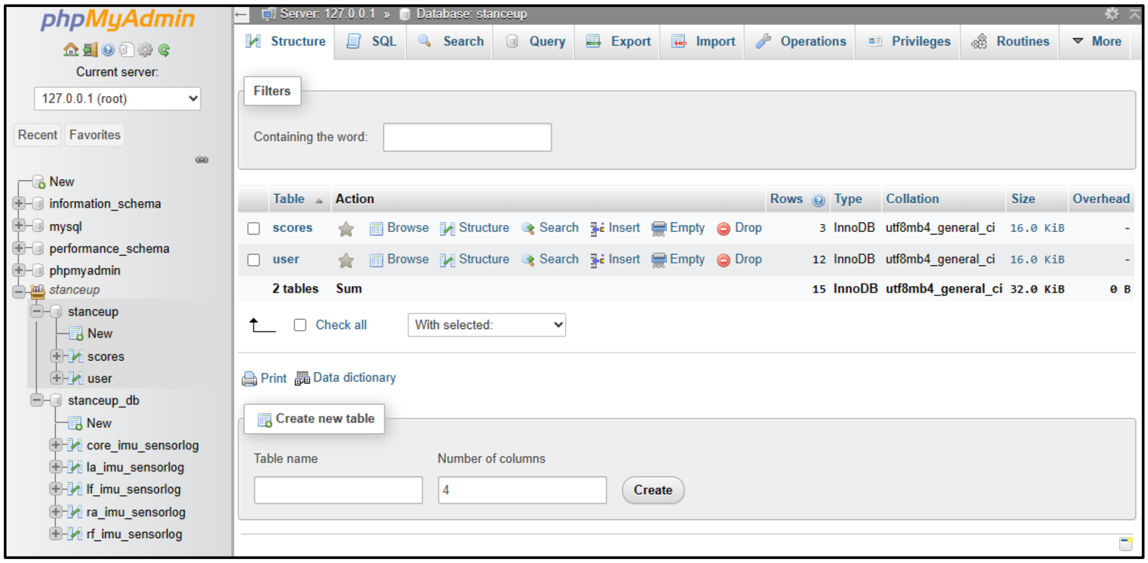


Figure 16. *Database System for the User Data, IMU Data, and Training Scores*

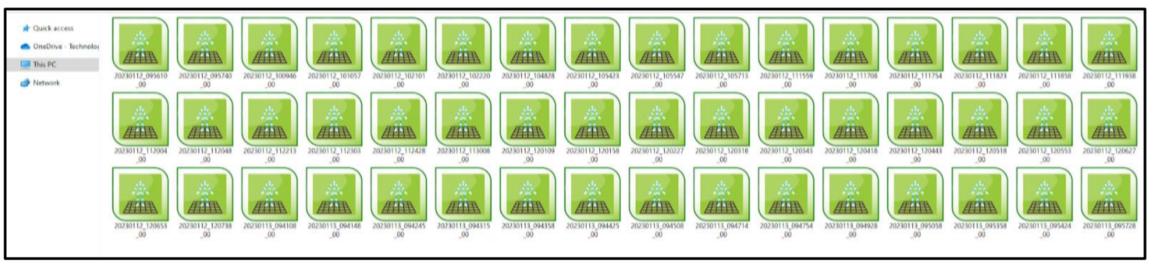


Figure 17. *Locally Hosted Database for the Kinect V2 Recordings*

3.4.6. Recording and Gathering of Datasets

The datasets needed came from the wearables placed on the body of the user. Another dataset was gathered from the Motion Capture Camera, which was the Microsoft Kinect V2. The recording and gathering of datasets for benchmarking had a time allotment of four to five months which was based on the availability of the athletes.

3.4.7 Storing and Combining Data from IMU and Kinect for Benchmarking Purposes

The benchmark data came from experienced and award-winning Taekwondo student-athletes. The collected data underwent cleaning, optimization, and fusion. This project adapted the data optimization and fusion techniques that were used in the Human Activity Recognition studies.

3.4.8 Storing and Combining Data from IMU and Kinect for Testing Purposes

The datasets that were gathered from the Taekwondo athletes were essential in assessing the system's efficiency and functionality. The combination of data from the Kinect and IMU sensors was necessary for the model application to the testing data.

3.5 Developing a Multi-Modal Algorithm for the Data Acquired from both the Kinect and IMU

To achieve the goal of the training system, Deep Learning algorithms like CNN were used to develop a model as a baseline of analysis for the testing datasets. According to the related literature of this study, the combination of CNN and LSTM managed to achieve results above 90% for systems using visual and IMU data [9]. With that, the study adapted and used a part of the recommended algorithm for this project study.

3.5.1 Coding and Training the Model

The study had to gather information from professional Taekwondo athletes. After the benchmark data gathering, the study had to prepare the coding and pre-processing of the data (i.e., data fusion, smoothing, and filtering). The data that was acquired was used to train the model. The optimization and processing of the data from both Kinect and IMU sensors were presented in the algorithm flowchart below (Figure 18 and 19).

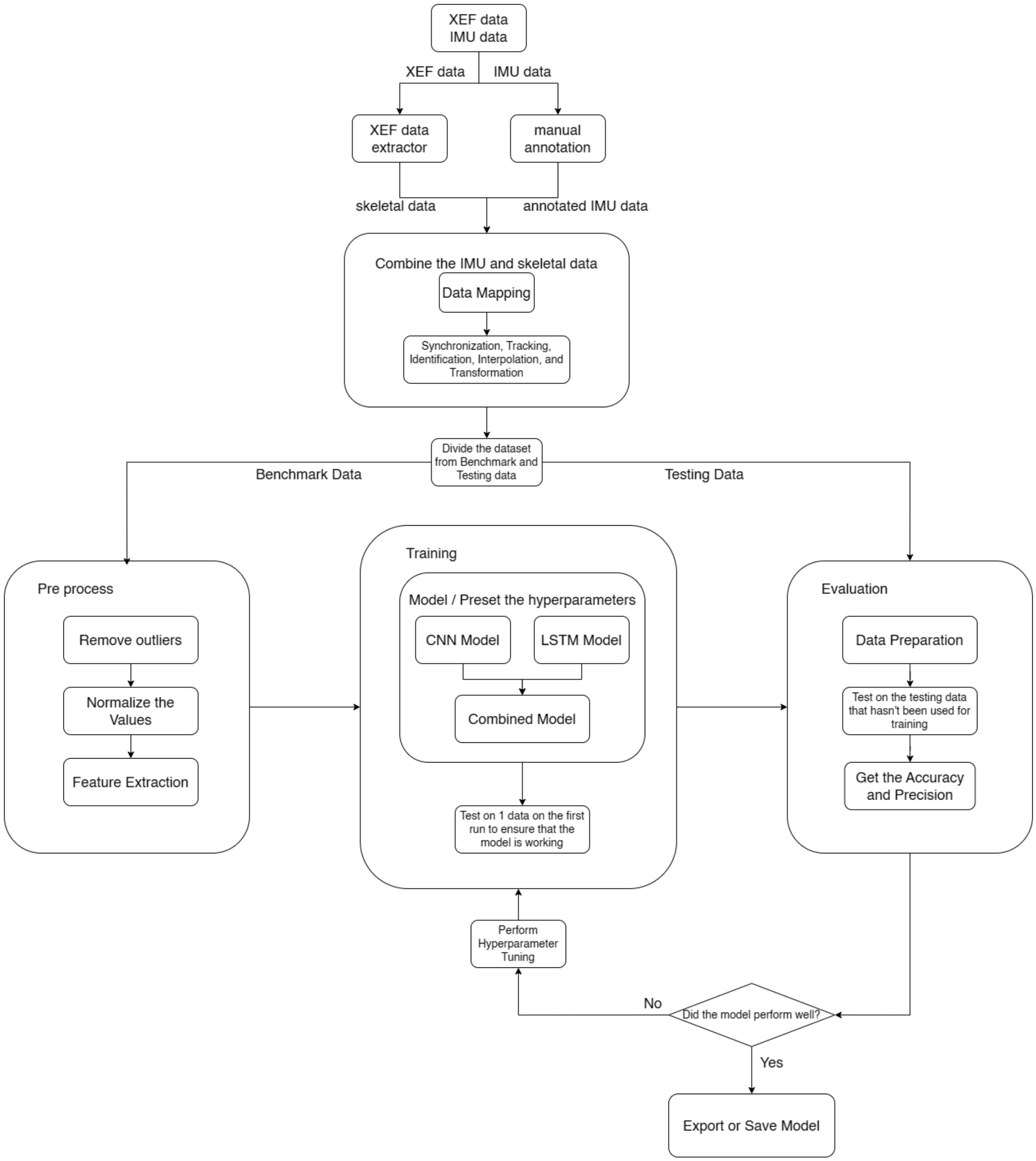


Figure 18. *Model Training*

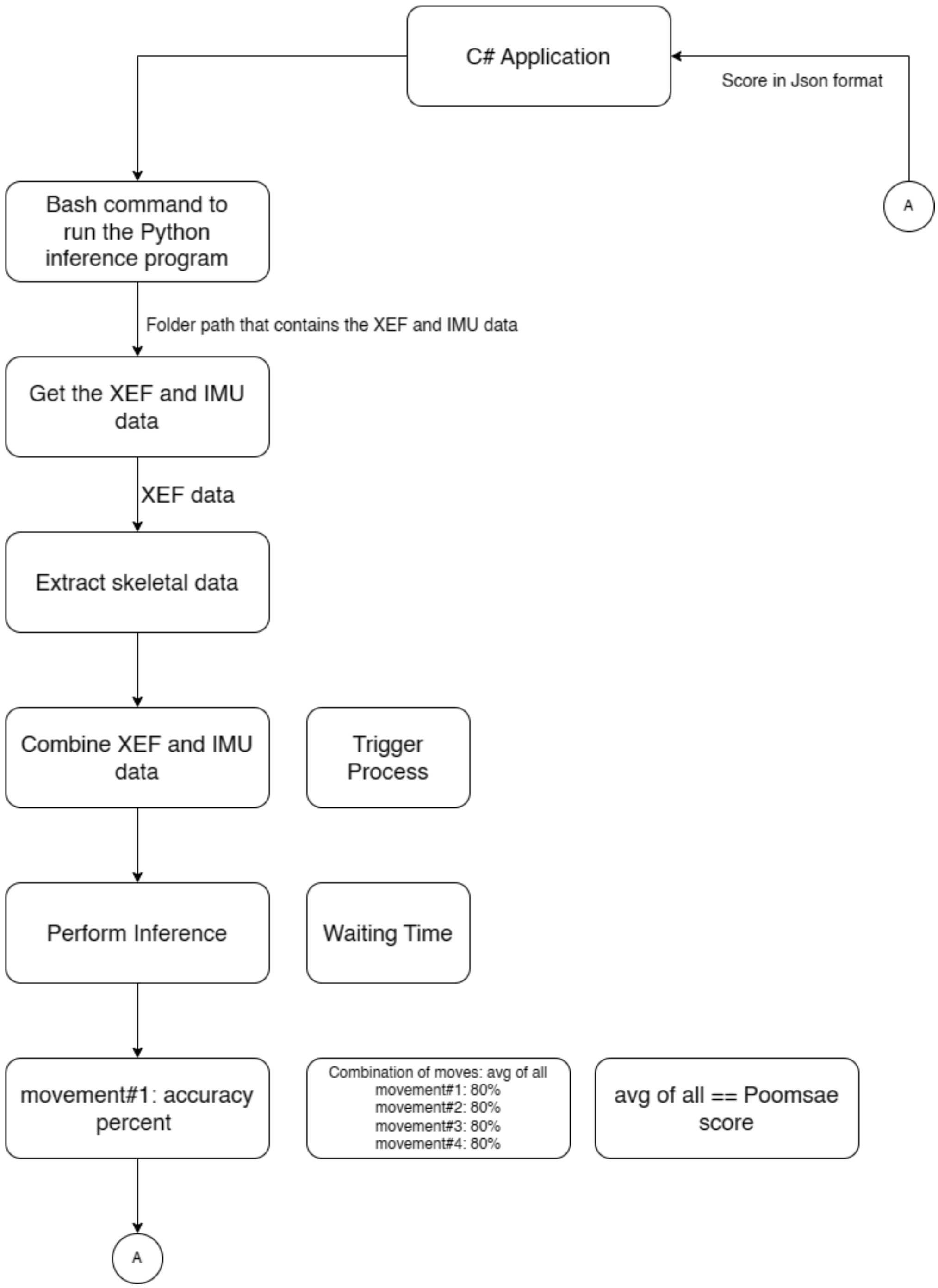


Figure 19. *Model Testing*

3.5.2 Applying the Model to the Benchmark and User Data

After the training and coding of the model, it was applied and integrated into the benchmarking datasets. Additionally, further modifications have been made to ensure the correctness of the model before the deployment of the project.

3.5.3 Get Accuracy Rate through Testing

Evaluating the Deep Learning algorithm was an essential part of this project study. This project study utilized the training scores that came as a result of the usage of the system. They were able to use the system output and compare it to the conventional way of scoring Taekwondo Poomsae movements.

3.5.4 Integrate Deep Learning Model into the Software

The final correct and trained model should be integrated into the desktop application to achieve its functionality for the project study.

3.6 Deployment and Testing of the System on TUP athletes and User Acceptance Tests

To test the effectiveness of the developed posture monitoring and detection system, it was deployed at the Technological University of the Philippines-Manila. Specifically, the participants were the Taekwondo athletes of TUP. After doing so, the proponents conducted user acceptance tests for feedback purposes.

3.6.1 Define the Testing Scope and Get Permissions to take part

The participants of this research were the Taekwondo athletes of the Technological University of the Philippines-Manila. With this, the proponents sent a letter to Prof. Allan D. Soria, director of the Sports and Development Department of TUP-Manila, to ask for permission to conduct the testing process. The Taekwondo coach and athletes were also notified.

3.6.2 Identify the Risks, Likelihood, and their Impact on the Testing Process

The researchers’ requirements were listed and prepared before the actual deployment in the testing location. Moreover, since the participation of the Taekwondo athletes had a huge role in the study, the schedule of all the athletes and coaches was considered in deciding the testing period to avoid schedule-related risks.

3.6.3 Actual Testing of the System on the Athletes

The deployment of the system was done at the Technological University of the Philippines-Manila. The testing process took place in a span of two weeks after the data gathering and benchmarking. The results collected were then analyzed using the chosen statistical analysis method to check the performance of the system and conclude its effectiveness.

3.6.4 Conduct User Acceptance Tests

After the testing process, the proponents conducted user acceptance tests in the form of surveys to gain feedback from the participants. Particularly, the questions included in the survey were based on ISO 9126 and ISO/TC 83. These ISO standards covered the field of software application development and exercising apparatus for sports.

3.7 Statistical Analysis

This study utilized data analysis and visualization to determine the effectiveness of the posture monitoring and detection device for Taekwondo Poomsae training. Statistical techniques based on the Likert scale were used to assess the performance of the system compared to the traditional scoring system [41]. For this study, the performance of the athletes with higher belt rank was regarded as a benchmark. Specifically, getting the average and comparison results was used to identify if there was a significant difference between the performance of the Taekwondo athletes before and after using the StanceUP posture monitoring and detection device.

3.8 Project Work Plan (Gantt Chart)

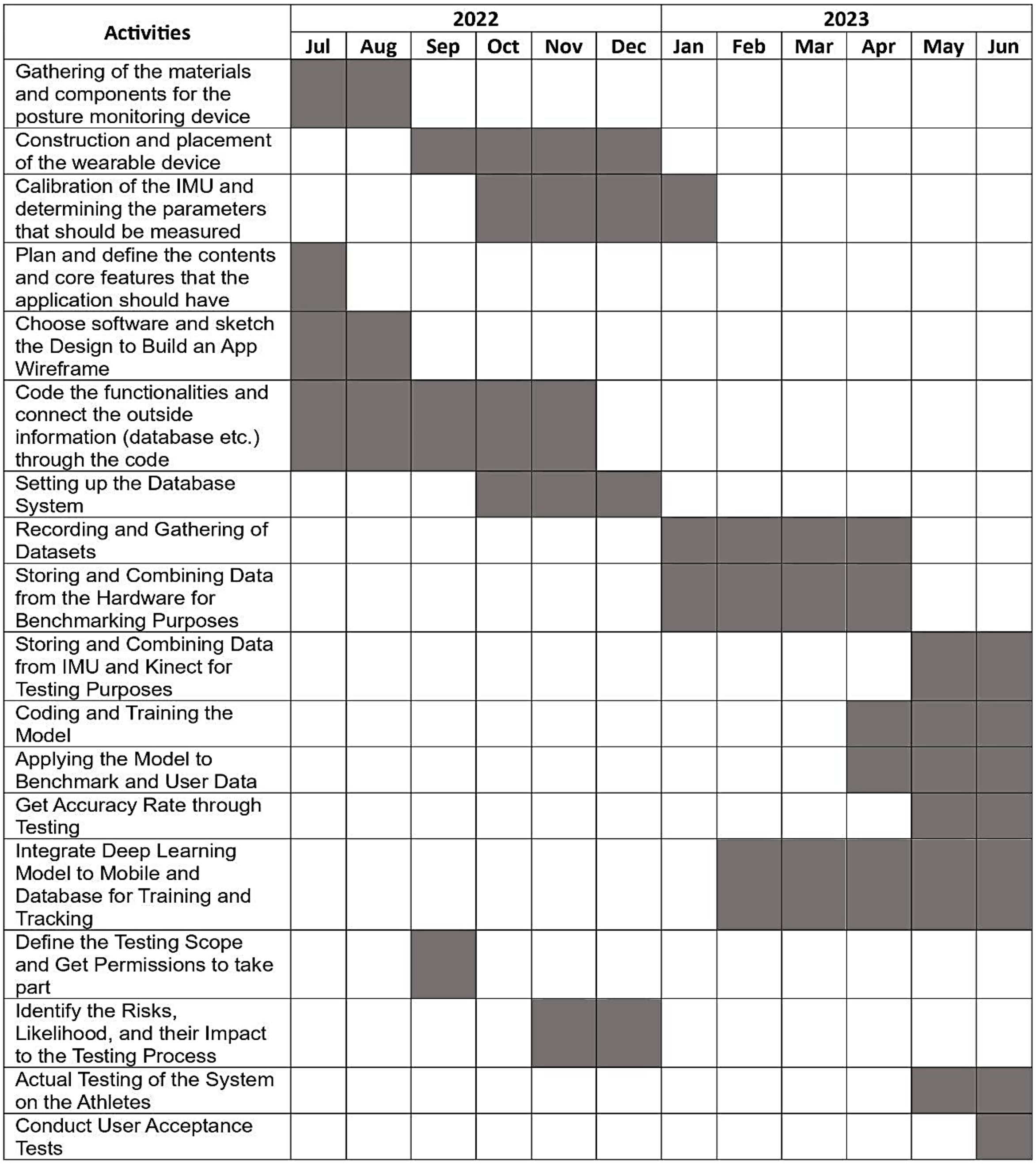


Figure 20. *Gantt Chart*

The figure above (Figure 20) represents the project work plan of this study. This figure also highlights the milestones and the percentage and duration of each task. The research activities started in July 2022 and were mostly done or completed by June 2023.

CHAPTER 4

DATA AND RESULTS

This chapter presents the project's technical description, project capabilities and limitations, project evaluation, and interpretation of the data and analysis of findings related to the tests conducted.

4.1 Project Technical Description

The study aimed to develop hardware and software systems for Taekwondo athletes whose main goal is to help the athletes in their Poomsae training. The working system should give the athletes numerical scores for their Poomsae form execution.

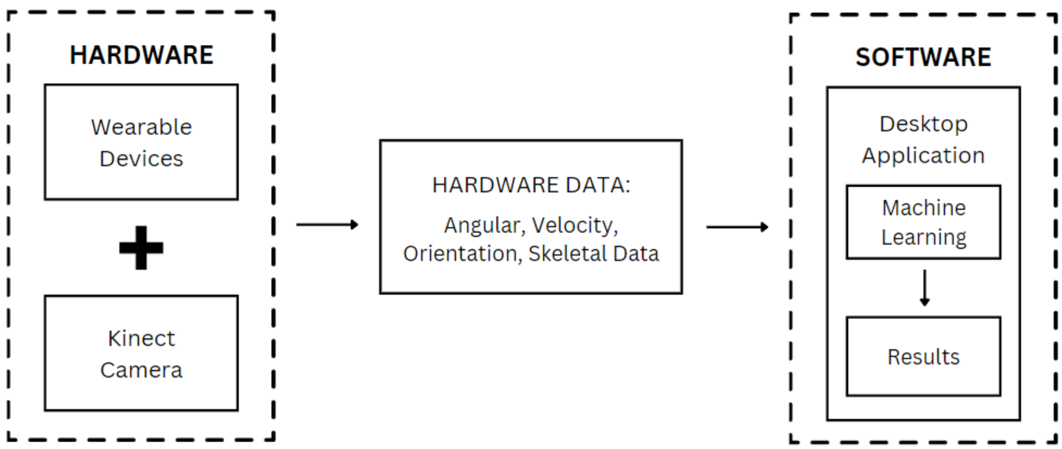


Figure 21. *StanceUP Block Diagram*

Figure 21 shows the block diagram of the whole StanceUP system. The hardware unit is responsible for getting the inertial and skeletal data that will serve as the input to the software section of the system. The software unit is responsible for processing the data gathered from the hardware setup and presenting the summary of the results to the users.

The software part of the project includes the main viewing application and machine learning model that is used for interpreting the data coming in from the hardware unit. CNN, which is mostly used for Human Action Recognition (HAR), is the same model that is being used for the project study.

4.2 Project Structural Organization

This section illustrates the detailed structure and parts of the project.

4.2.1 Hardware

The hardware comprises five (5) wearables and a Kinect camera sensor shown in Figure 22 and Figure 23, respectively. The wearables have a maximum of three (3) hours of battery life each. Each wearable is composed of NodeMCU, GY-91 IMU, OLED display, 3.7V LiPo Battery, battery charging port, 5V step-up regulator, and a switch. The chassis of the wearable is 3D printed using PETG filament and has 3.150 inches x 2.740 inches x 1.200 inches (80mm x 60mm) dimensions. The placement of the five (5) wearables on a user's body can be seen in Figure 24. It should also be noted that there are indicators in the LED shown to specify the body part where each wearable must be placed.

Figure 22. *The five (5) wearables*

Figure 23. *Kinect sensor*

Figure 24. *Placement of wearables*

4.2.2 Software Application

This section shows the overview of the software application made by the researchers to supplement the StanceUP training system. The researchers have completed the development of a Desktop Application. This application was utilized by the users for their training sessions and viewing of their data.

4.2.2.1 Screenshots of the Desktop Application

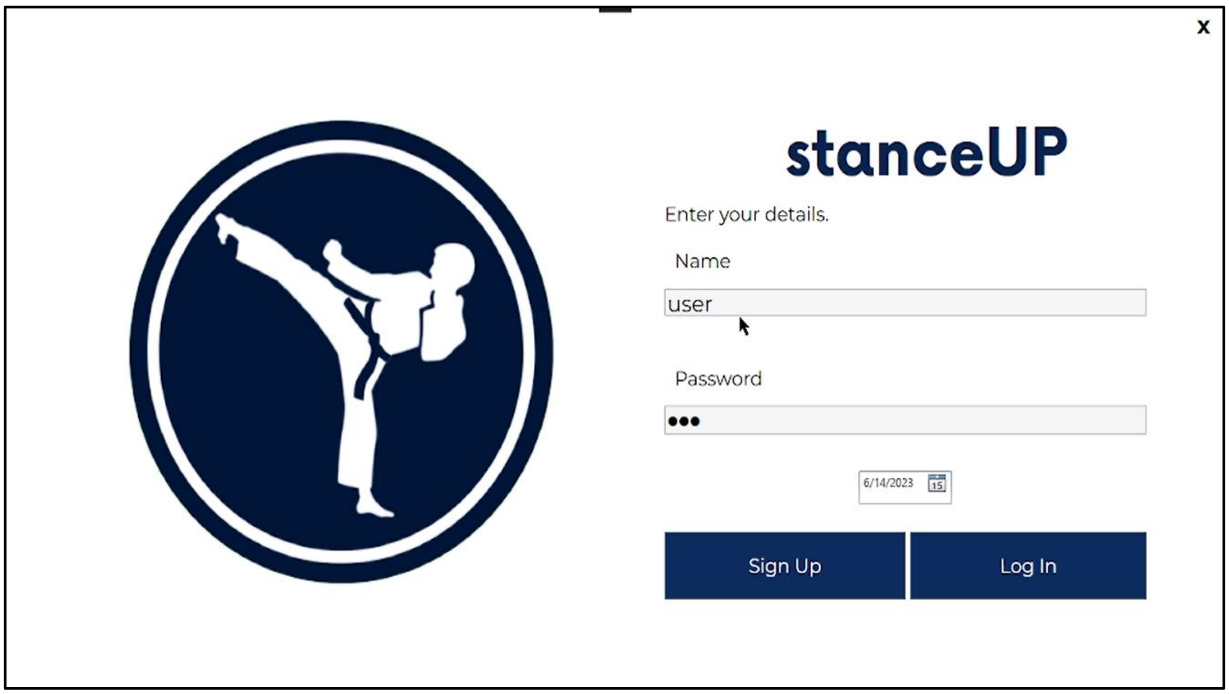
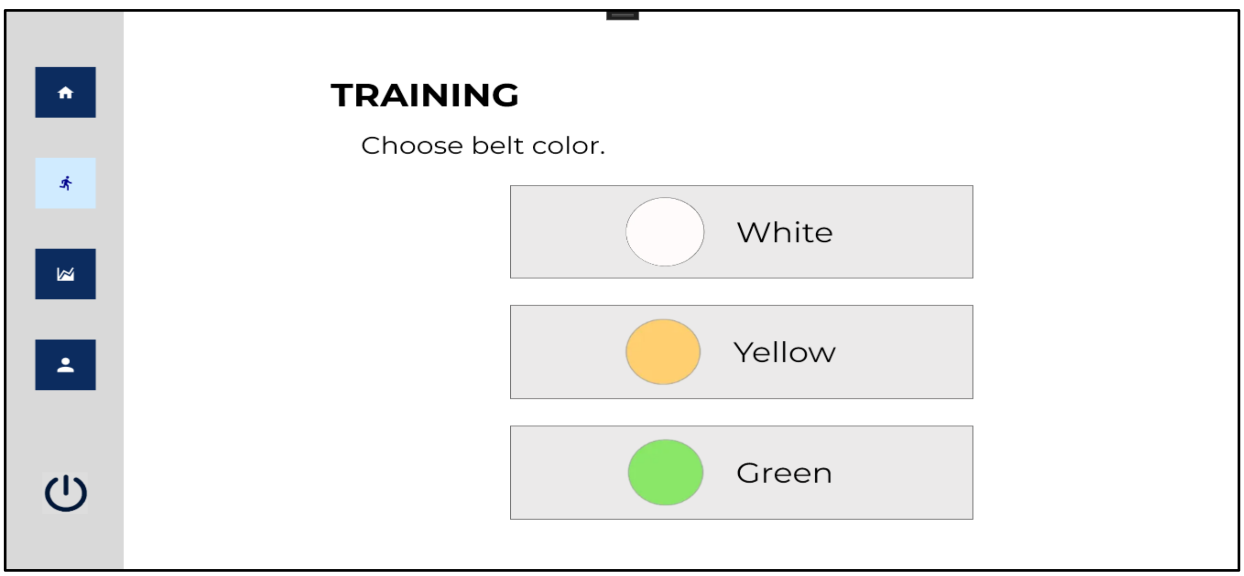


Figure 25. *Desktop App's Sign-Up and Log-In Page*

Figure 25 shows the sign up/log in page of the application, which enables users to create or open their existing accounts. Each user needs an account so that the data such as time of training and scores gathered from their training sessions can be stored in the database and be shown in their application accordingly.

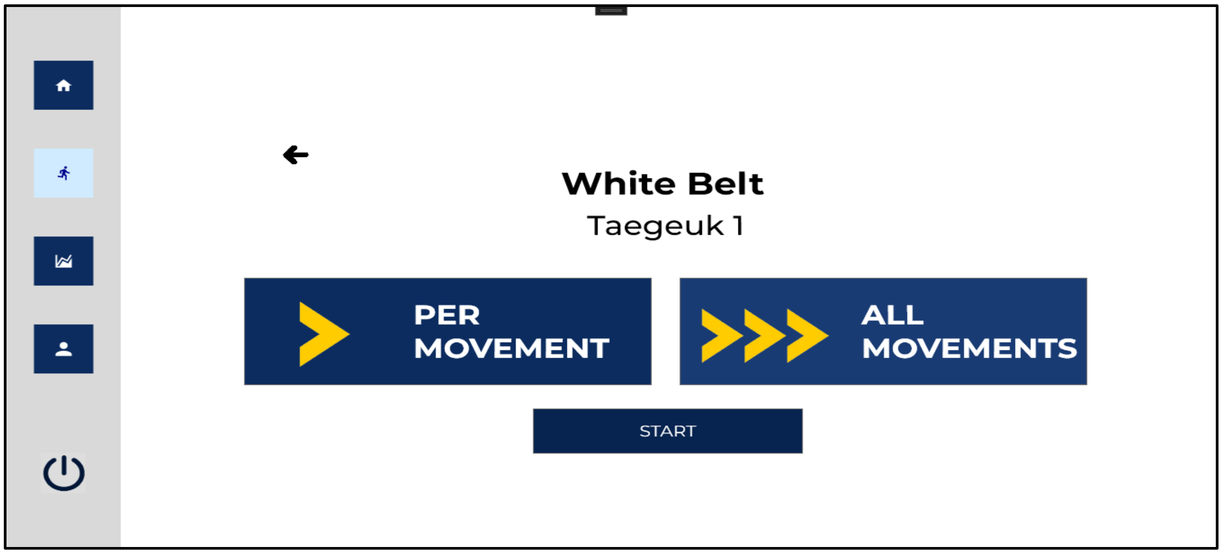
Figure 26. *Desktop App's Main Window*

Figure 26 exhibits the main window of the application which means that the creation of account or log in was successful.



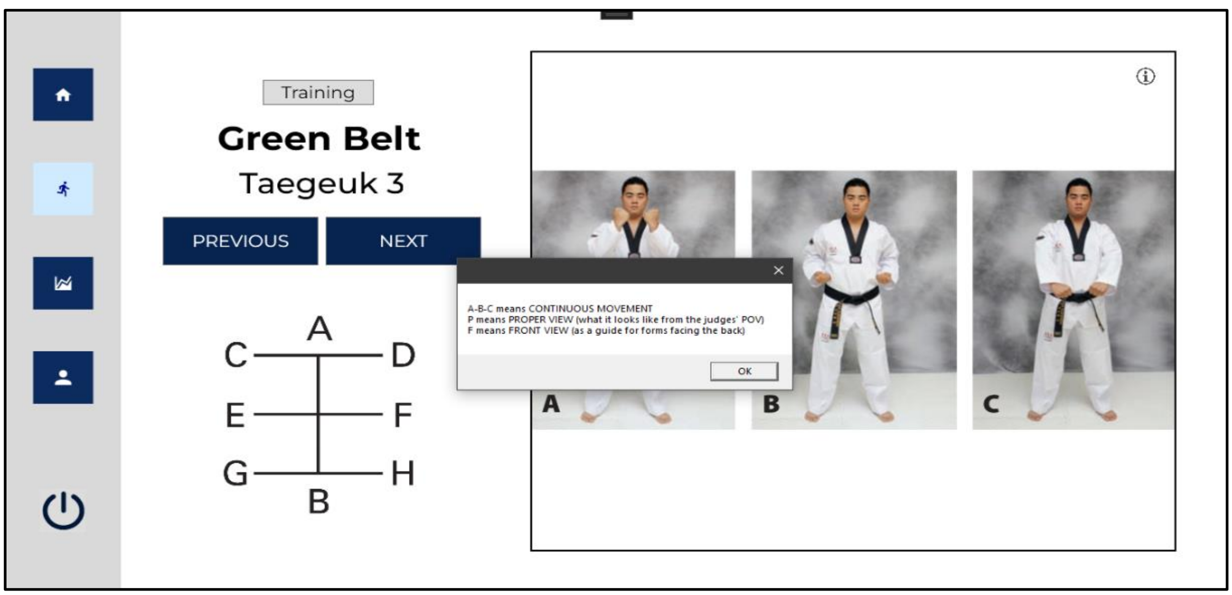
(a) *Page for the training levels*

Figure 27-a displays the belt colors available in the application. The colors correspond to their respective Taegeuk level and have different sequences of stance and movements.



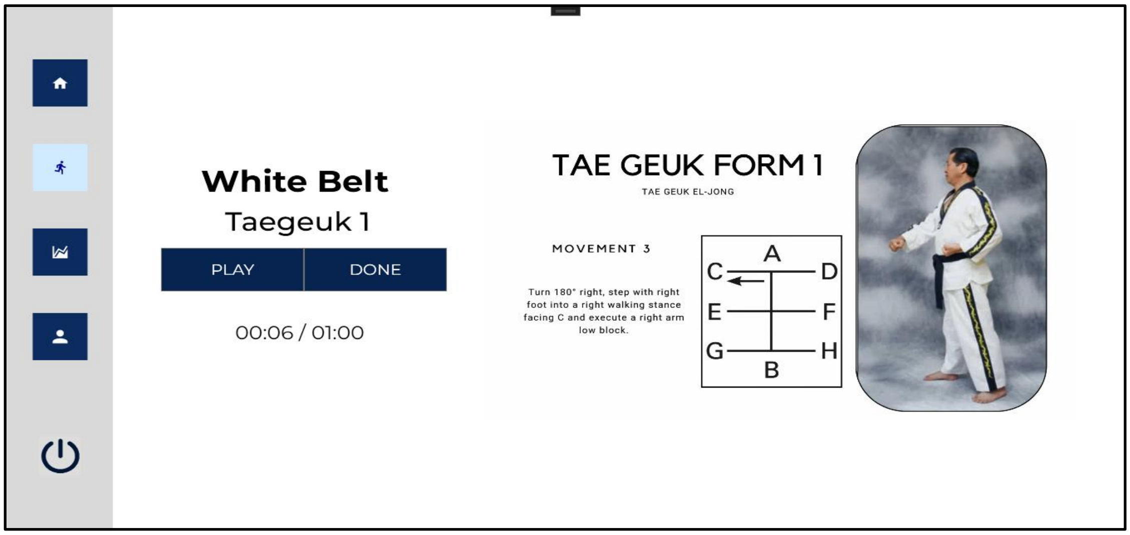
(b) *Page for the level review and recording options.*

Figure 27-b displays the user interface of the application's training mode. In this feature, the users could choose to check tutorials first or proceed to the recording process.



(c) *Page for reviewing Poomsae through pictures*

This figure shows the user interface for the "per movement" tutorial. Here, the users can review the steps one-by-one. A guide is provided for the right position and cadence of certain movements.



(d) *Page for reviewing Poomsae through videos*

Shown in the figure above is the user interface of the "all movements" tutorial wherein the users can view a continuous sequence of the stances and movements in a form of a video.

(e) *Page for the recording feature of the application*

Figure 27a - e. *Desktop App's Training Pages*

Figure 27-e shows where the users can record their skeletal data through the Kinect, get their angular and orientation data through the IMUs and submit them to the system. Their performance will then be analyzed by the system and will be scored accordingly.

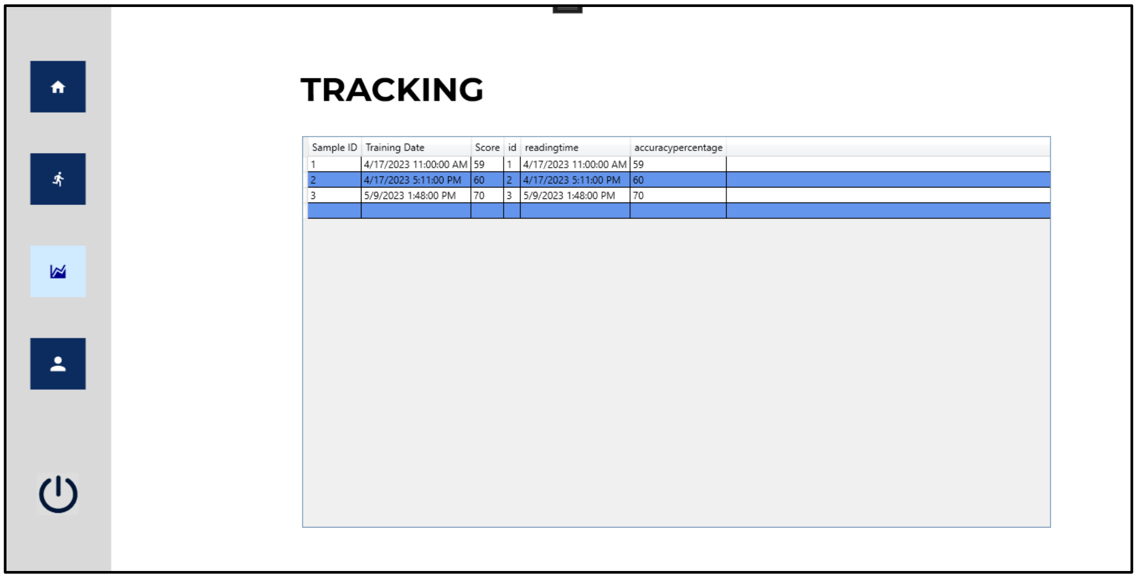


Figure 28. *Desktop App's Tracking Page*

Figure 28 shows the tracking mode of the application. The scores obtained by the user from their recordings in the training mode will be displayed here.

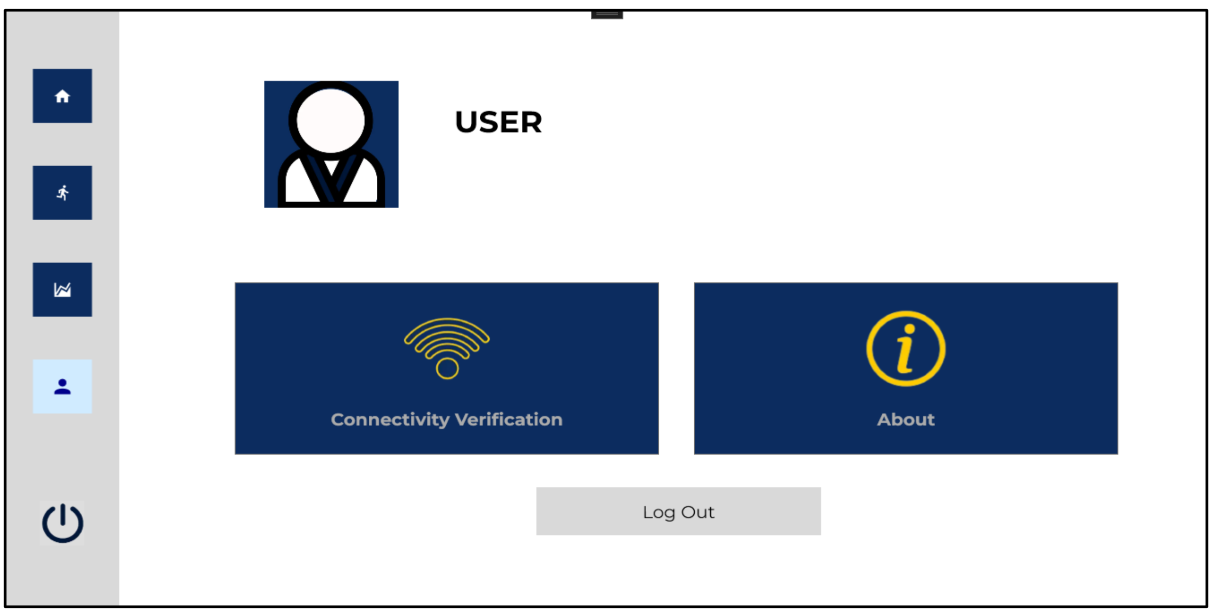
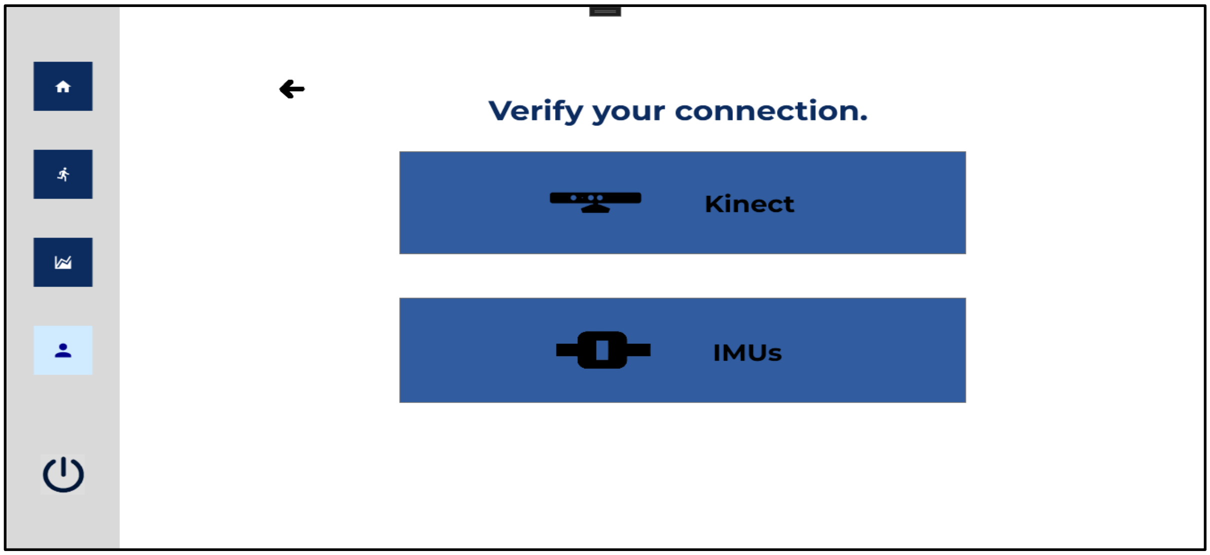


Figure 29. *Desktop App's Other Features Page*

Shown in Figure 29 is the account page, where the other features of the application such as connectivity verification of the hardware are located.

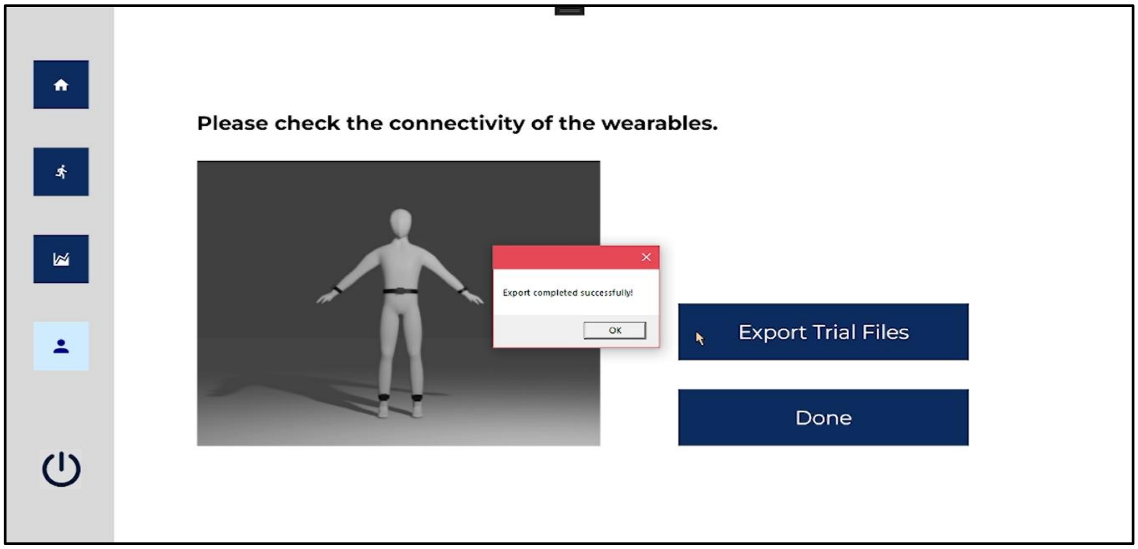


(a) *Page for choosing the device that should undergo connectivity verification.*

Since the system utilizes the combination of the IMUs and Kinect, the application has a feature wherein users can separately check their connectivity, as shown in Figure 30-a.

(b) *Page for Verifying Kinect Connectivity*

Figure 30-b displays the user interface of the feature wherein the users can check if the Kinect camera is connected. Specifically, the video streams shown are the infrared (IR), Depth, Body Index, and Body views.



(c) Page *for Verifying IMU/Wearables Connectivity*

Figure 30a - c. *Desktop App's Verifying Connectivity Pages*

Figure 30-c shows a photo guide about the placement of the wearable devices. Trial files can also be exported to check if the wearables send data to the local database.

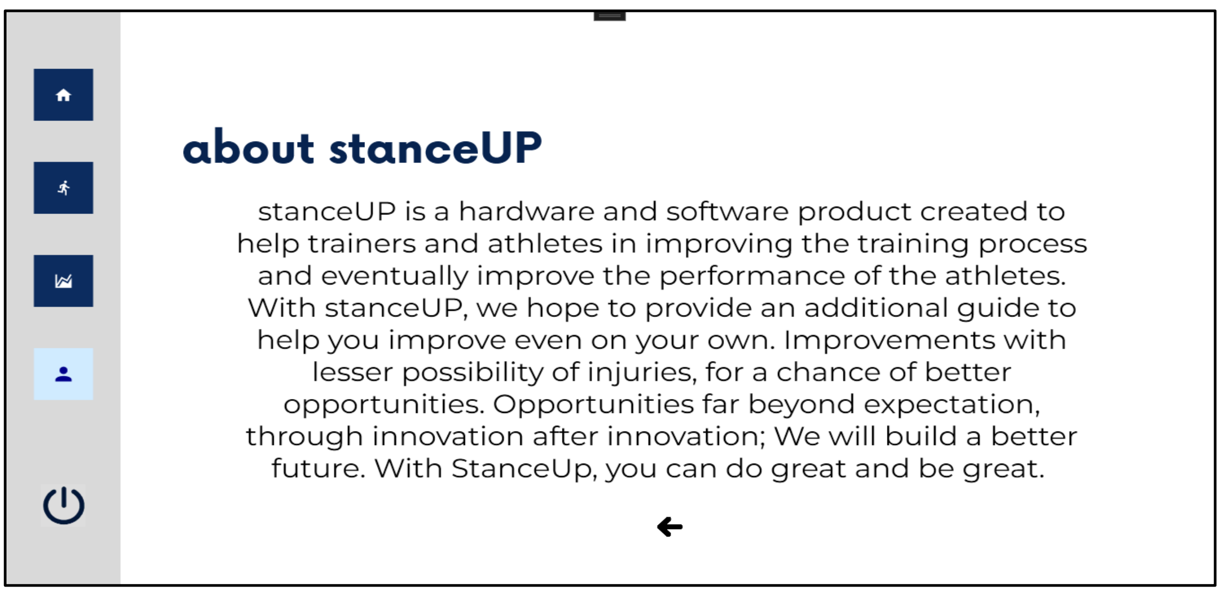
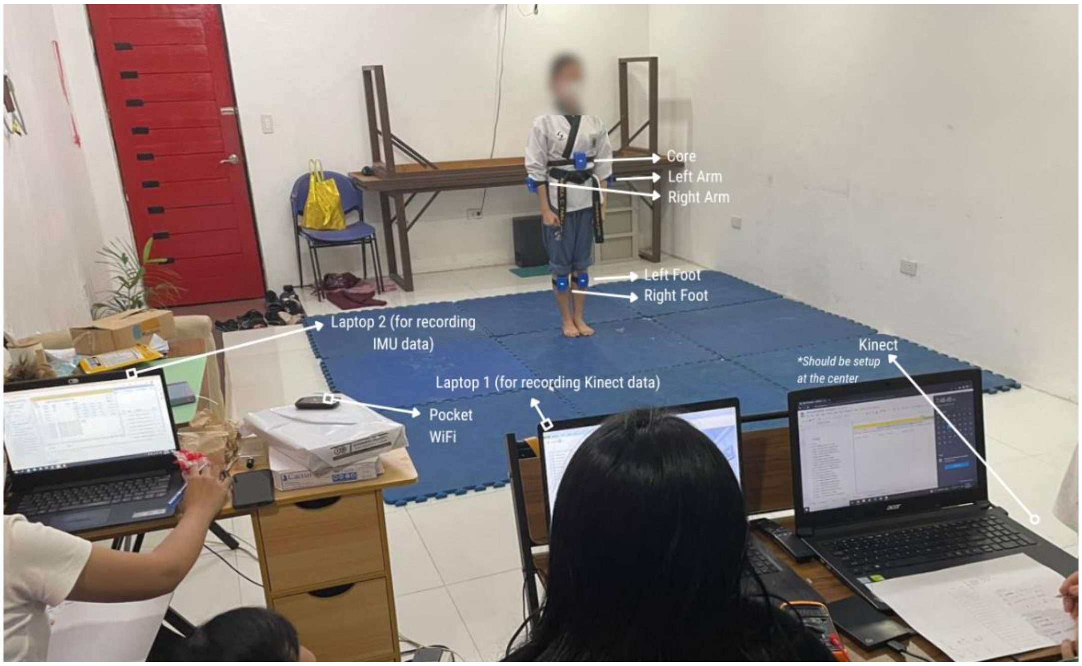


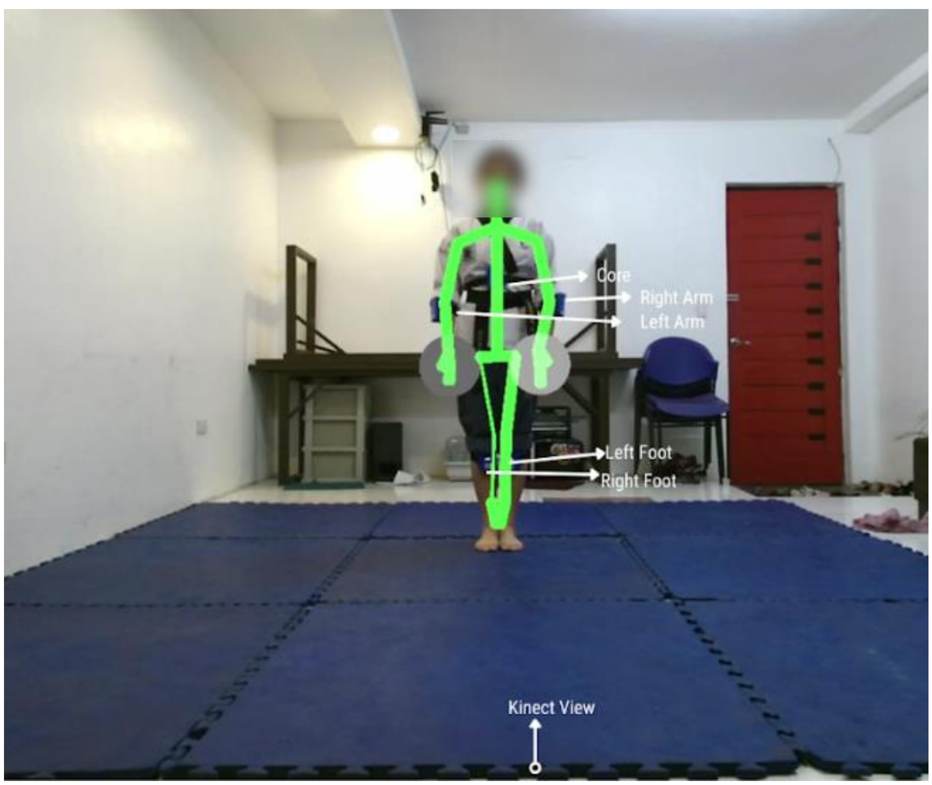
Figure 31. *Desktop App's About StanceUP Page*

Shown in Figure 31 is the page where a description about StanceUP is displayed. Specifically, the project's goal for its end users is included.

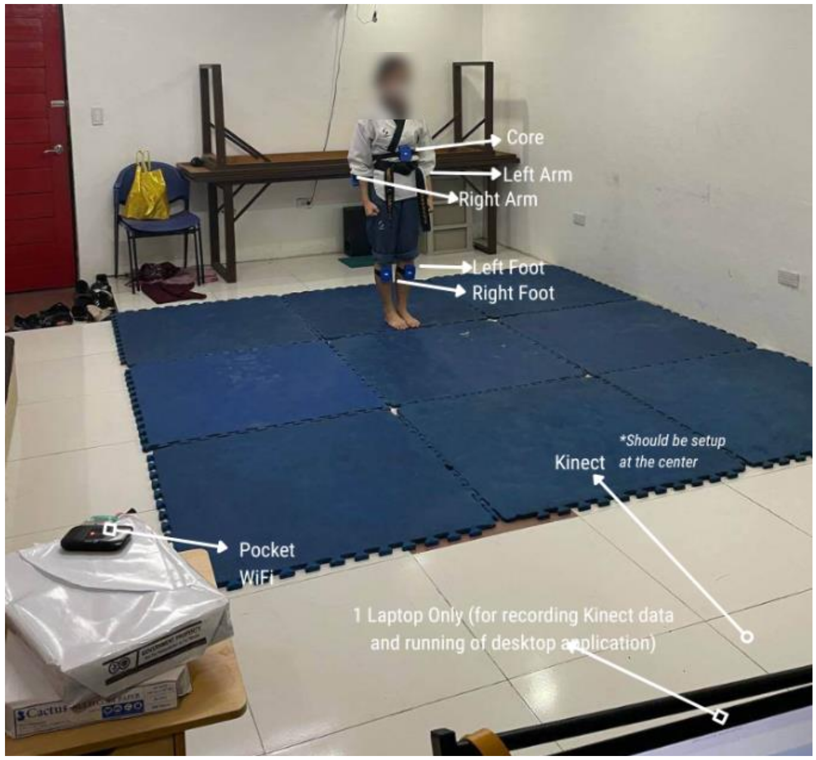
4.2.3 Connection of the Hardware and Software



(a)



(b)



(c)

Figure 32a - c. *Overall Setup*

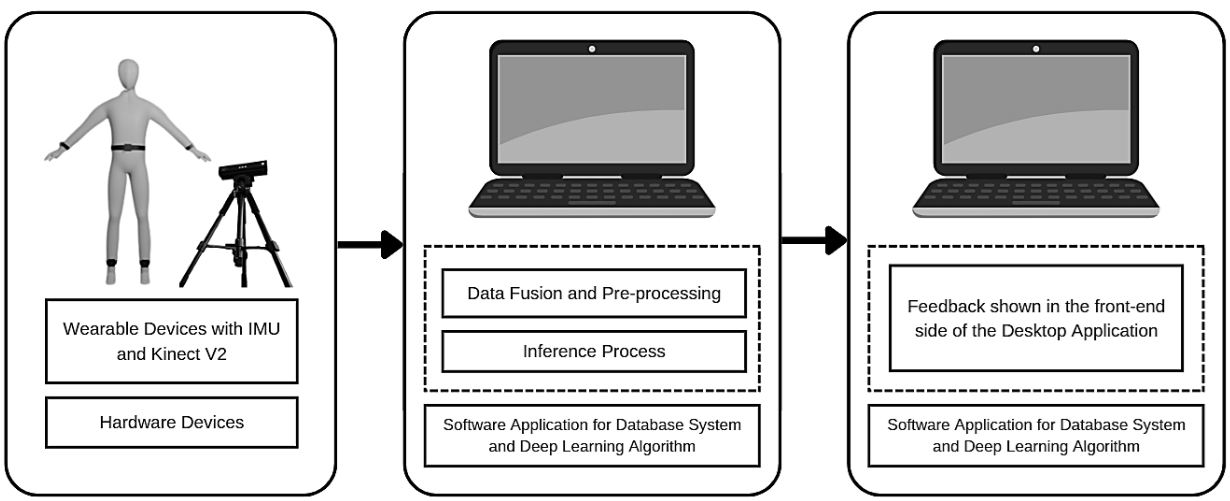


Figure 33. *One-line System Diagram*

Figure 32a-c shows the overall developed system of StanceUP. These figures show how the hardware devices should be set up and how the software application should be utilized during the data gathering process. Figure 33 is the one-line diagram of the system. This shows the connectivity between the developed systems and their corresponding processes.

4.3 Project Capabilities and Limitations

Project StanceUP has the following capabilities:

1. Wireless record of data from the wearables and Kinect Sensors in accordance with the training time of the athletes.
2. Collect posture parameters of Poomsae Forms from Taegeuk 1 and give scores.
3. Show the athlete's score based on his/her performance.
4. Store the user data for tracking improvements.
5. Show the athlete’s statistics for training.

On the other hand, some limitations are seen in the project:

1. The scores from the inference process cannot be provided in real-time as developer intervention is required to input the recorded data from the training sessions into the multi-modal recognition algorithm.
2. The wearables can only be used continuously for 3 hours, and so the battery capacity is limited for long-term use.

4.4 Project Evaluation and Results

This section of the paper shows all the results from the testing done before and during the initial data gathering, and deployment period.

4.4.1 Calibration and Accuracy Testing

The researchers were able to test the accuracy of the wearables by comparing them to other commercially available Inertial Measurement Units like the MPU 6050 and the in-built one on smartphones. The researchers were able to utilize the in-built IMU on the phone using the VibraTilt application. VibraTilt is a free smartphone application available on IOS and Android that is utilized for scientific purposes [45].

The tables below show the accuracy tests done on wearable devices. To check their accuracy, the researchers changed the position of the wearables and recorded two repetitions per position.

The highest accuracy percentage is 100% for g/Acceleration, Angles, and Orientation data when GY-91 is compared to another commercially produced IMU which is the MPU-6050 (Tables 9-13 and Figures 34-38). However, there are two instances where the accuracy percentage went below 70%. This may potentially be caused by the unleveled placement of both the wearable and IMU or an inertial drift.

Table 9. Accuracy Tests for the Right-Foot Wearable

RIGHT FOOT		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
GY-91	Acceleration (g's)	1.00	1.00	-1.01	-1.01	0.95	0.95	-1.04	-1.04	1.01	1.01	-0.99	-0.99
	Angles (deg)	88.57	87.98	-90.00	-90.00	71.72	72.14	-90.00	-90.00	90.00	90.00	-79.70	-79.70
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
MPU-6050	Acceleration (g's)	1.00	1.00	-0.99	-1.00	1.04	1.04	-0.96	-0.96	0.99	0.99	-1.03	-1.04
	Angles (deg)	90.00	90.00	-83.64	-84.17	90.00	90.00	-73.43	-72.82	80.67	80.62	-90.00	-90.00
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
Accuracy	Acceleration (g's)	100.00	100.00	97.98	99.00	91.35	91.35	91.67	91.67	97.98	97.98	95.15	94.23
	Angles (deg)	98.41	97.76	92.40	93.07	79.69	80.16	77.43	76.41	88.43	88.37	88.56	88.56
	Orientation	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

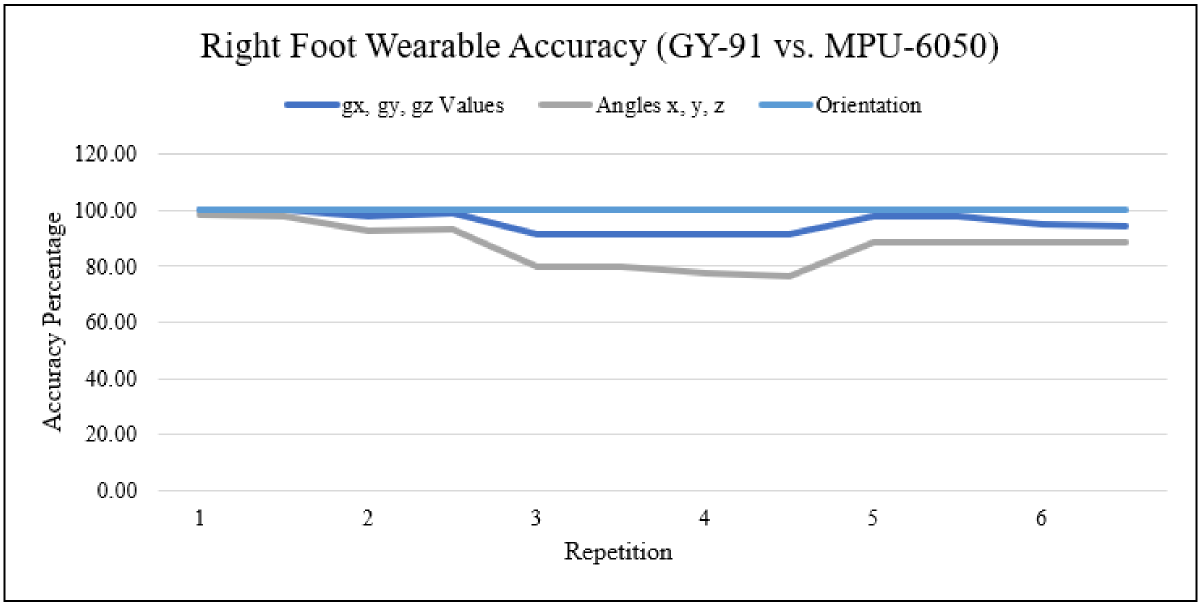


Figure 34. *Right Foot Wearable Accuracy (GY-91 vs. MPU-6050)*

Table 9 and Figure 34 show the accuracy of the Right Foot Wearable. From the accuracy testing, the accuracy of g Values ranges from 91.35% to 100%, angles' accuracy ranges from 76.41% to 98.41%, and all the orientation values reached a 100% accuracy.

Table 10. Accuracy Tests for the Right Arm Wearable

RIGHT ARM		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
GY-91	Acceleration (g's)	1	1	-1	-1	0.91	0.91	-1.08	-1.08	1.01	1.01	-0.99	-0.99
	Angles (deg)	86.95	90	-90	-90	65.02	65.26	-90	-90	90	90	-82.57	-82.9
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
MPU-6050	Acceleration (g's)	1	1	-0.99	-0.99	1.06	1.06	-0.94	-0.94	0.98	0.98	-1.02	-1.03
	Angles (deg)	90	90	-82.5	-82.5	90	90	-70.34	-70.2	79.69	79.35	-90	-90
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
Accuracy	Acceleration (g's)	100.00	100.00	98.99	98.99	85.85	85.85	85.11	85.11	96.94	96.94	97.06	96.12
	Angles (deg)	96.61	100.00	90.91	90.91	72.24	72.51	72.05	71.79	87.06	86.58	91.74	92.11
	Orientation	100	100	100	100	100	100	100	100	100	100	100	100

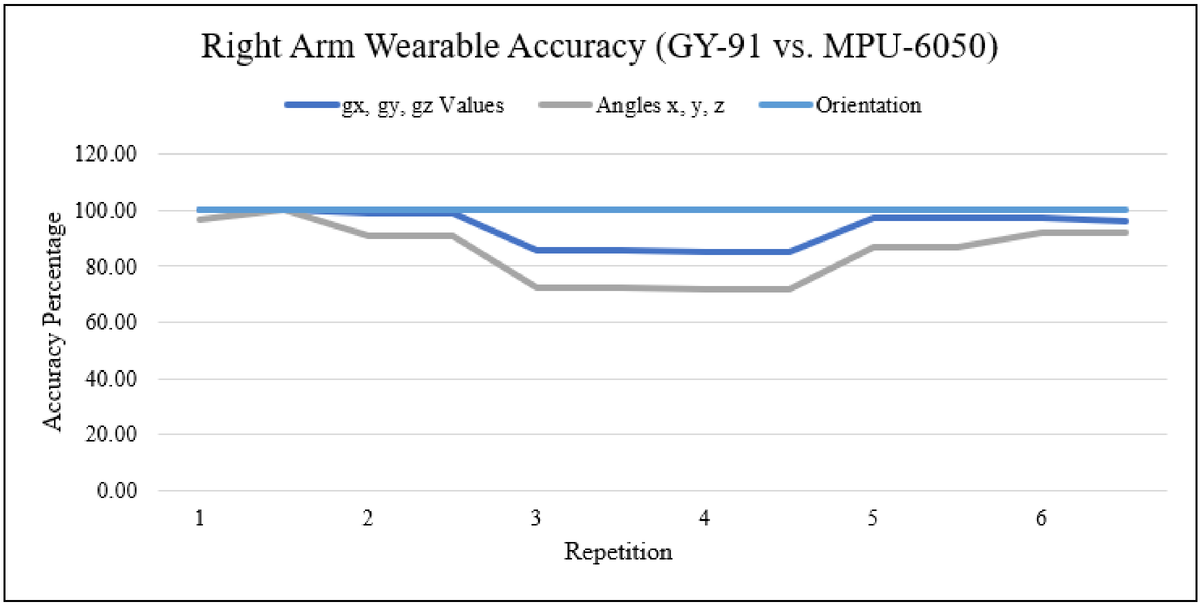


Figure 35. *Right Arm Wearable Accuracy (GY-91 vs. MPU-6050)*

Table 10 and Figure 35 show the accuracy of the Right Arm Wearable. From the accuracy testing, the accuracy of g Values ranges from 85.11% to 100%, angles' accuracy ranges from 71.79% to 100%, and all the orientation values reached a 100% accuracy.

Table 11. Accuracy Tests for the Core Wearable

CORE		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
GY-91	Acceleration (g's)	1	1	-1	-1	0.95	0.95	-1.04	-1.04	1	1	-1	-1
	Angles (deg)	90	90	-85	-84.22	71.68	71.45	-90	-90	90	90	-84.42	-84.57
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
MPU-6050	Acceleration (g's)	1	1	-0.99	-0.99	1.04	1.04	-0.96	-0.96	1	1	-1.01	-1.01
	Angles (deg)	90	90	-83.53	-83.45	90	90	-73.61	-73.42	84.29	88.53	-90	-90
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
Accuracy	Acceleration (g's)	100.00	100.00	98.99	98.99	91.35	91.35	91.67	91.67	100.00	100.00	99.01	99.01
	Angles (deg)	100.00	100.00	98.24	99.08	79.64	79.39	77.73	77.42	93.23	98.34	93.80	93.97
	Orientation	100	100	100	100	100	100	100	100	100	100	100	100

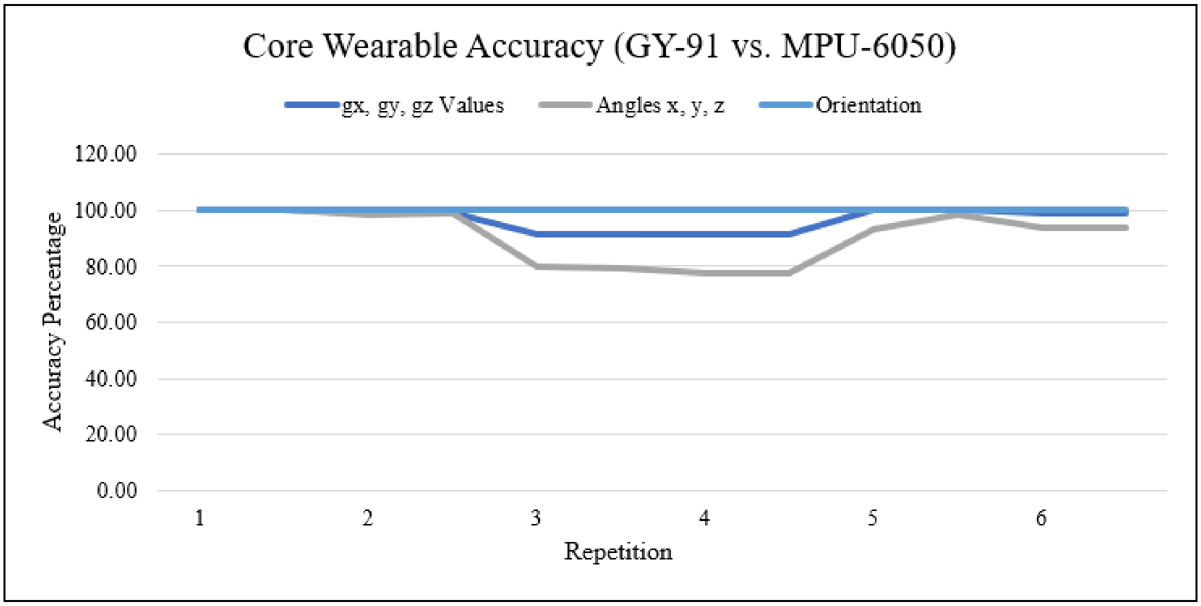


Figure 36. *Core Wearable Accuracy (GY-91 vs. MPU-6050)*

Table 11 and Figure 36 show the accuracy of the Core Wearable. From the accuracy testing, the accuracy of g Values ranges from 91.67% to 100%, angles' accuracy ranges from 77.42% to 100%, and all the orientation values reached a 100% accuracy.

Table 12. Accuracy Tests for the Left Foot Wearable

LEFT FOOT		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
GY-91	Acceleration (g's)	1	1	-1.01	-1.01	0.99	0.99	-1.01	-1.01	1	1	-1	-1
	Angles (deg)	90	88.26	-90	-90	80.58	80.33	-90	-90	85.2	85	-90	-90
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
MPU-6050	Acceleration (g's)	1	1	-1	-1	1.03	1.03	-0.96	-0.97	0.97	0.98	-1.03	-1.04
	Angles (deg)	86.46	85.56	-86.27	-85.96	90	90	-74.46	-74.48	76.66	77.16	-90	-90
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
Accuracy	Acceleration (g's)	100.00	100.00	99.00	99.00	96.12	96.12	94.79	95.88	96.91	97.96	97.09	96.15
	Angles (deg)	95.91	96.84	95.68	95.30	89.53	89.26	79.13	79.16	88.86	89.84	100.00	100.00
	Orientation	100	100	100	100	100	100	100	100	100	100	100	100

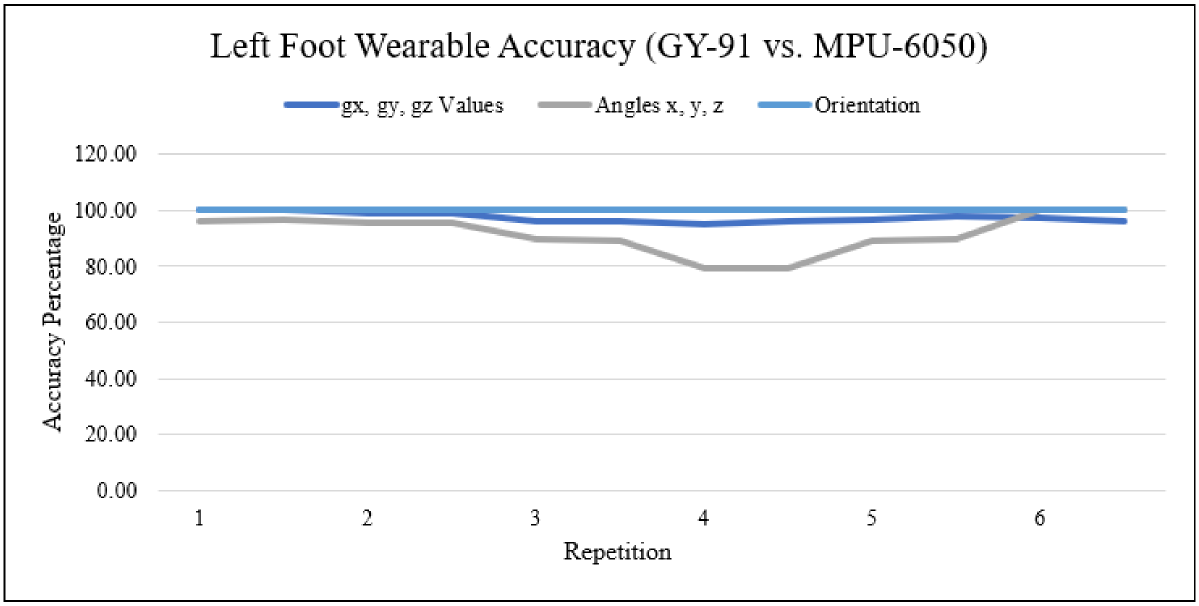


Figure 37. *Left Foot Wearable Accuracy (GY-91 vs. MPU-6050)*

Table 12 and Figure 37 show the accuracy of the Left Foot Wearable. From the accuracy testing, the accuracy of g Values ranges from 94.79% to 100%, angles' accuracy ranges from 79.13% to 100%, and all the orientation values reached a 100% accuracy.

Table 13. Accuracy Tests for the Left Arm Wearable

LEFT ARM		**POS 1**		**POS 2**		**POS 3**		**POS 4**		**POS 5**		**POS 6**	
		z-axis				**x-axis**				**y-axis**			
		REP 1	**REP 2**	**REP 1**	**REP 2**	**REP 1**	**REP 2**	**REP 1**	**REP 2**	**REP 1**	**REP 2**	**REP 1**	**REP 2**
GY-91	**Acceleration (g's)**	1	1	-1.02	-1.01	1.01	1.01	-0.98	-0.98	1	1	-0.99	-1
	Angles (deg)	87.89	87.99	-90	-90	90	90	-77.41	-79.91	90	90	-82.61	-86.7
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
MPU-6050	**Acceleration (g's)**	1	1	-1	-1	0.99	0.99	-1	-1.01	1.12	1.12	-0.89	-0.89
	Angles (deg)	90	90	-84.17	-86.27	81.74	82.04	-90	-90	90	90	-62.9	-62.75
	Orientation	z up	z up	z down	z down	x up	x up	x down	x down	y up	y up	y down	y down
Accuracy	**Acceleration (g's)**	100.00	100.00	98.00	99.00	97.98	97.98	98.00	97.03	89.29	89.29	88.76	87.64
	Angles (deg)	97.66	97.77	93.07	95.68	89.89	90.30	86.01	88.79	100.00	100.00	68.66	61.83
	Orientation	100	100	100	100	100	100	100	100	100	100	100	100

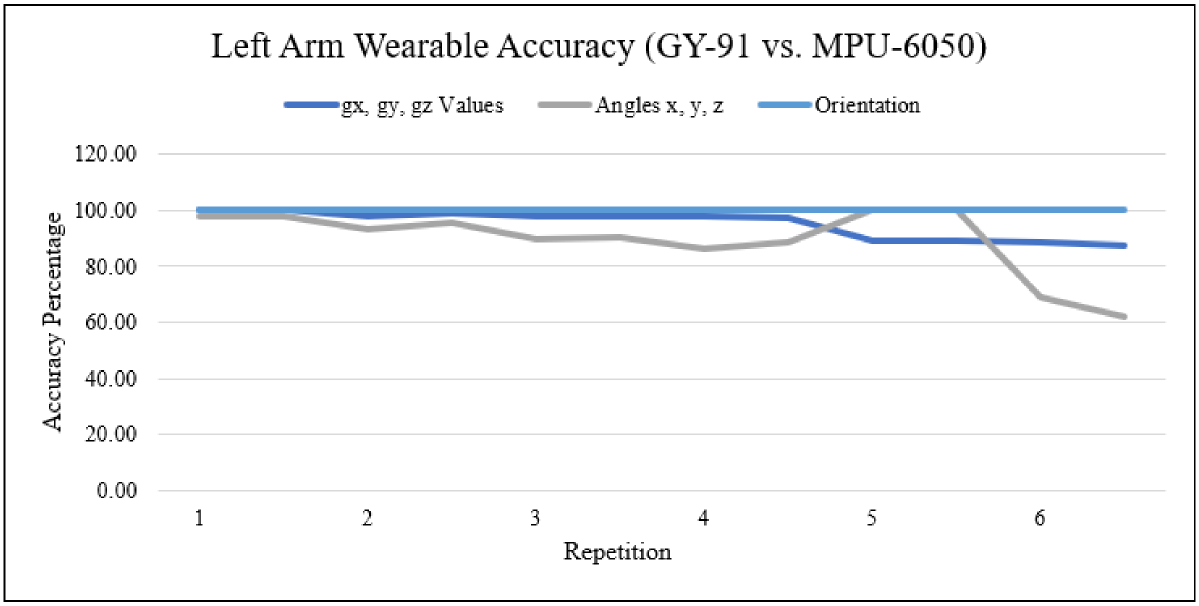


Figure 38. *Left Arm Wearable Accuracy (GY-91 vs. MPU-6050)*

Table 13 and Figure 38 show the accuracy of the Left Arm Wearable. From the accuracy testing, the accuracy of g Values ranges from 87.64% to 100%, angles' accuracy ranges from 61.83% to 100%, and all the orientation values reached a 100% accuracy.

When GY-91 is compared to the in-built IMU on a smartphone, the highest accuracy percentage is 100% for g/Acceleration data. The lowest accuracy percentage is 91% and this may potentially be caused by the unleveled placement of both the wearable and IMU (Tables 14-18, and Figure 39).

Table 14. Accuracy Percentages for the Right Foot Wearable

RIGHT FOOT		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
Acceleration (g's)	GY-91	1.00	1.00	1.01	1.01	0.95	0.95	1.04	1.04	1.01	1.01	0.98	0.98
		9.80	9.80	9.90	9.90	9.31	9.31	10.19	10.19	9.90	9.90	9.60	9.60
	VibraTilt	9.70	9.70	9.90	9.90	9.80	9.80	9.80	9.80	9.50	9.50	10.10	10.10
Accuracy	g Values	98.97	98.97	99.98	99.98	95.00	95.00	96.00	96.00	95.81	95.81	95.09	95.09

Table 15. Accuracy Percentages for the Right Arm Wearable

RIGHT ARM		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
Acceleration (g's)	GY-91	1.00	1.00	1.00	1.00	0.91	0.91	1.08	1.08	1.01	1.01	0.99	0.99
		9.80	9.80	9.80	9.80	8.92	8.92	10.58	10.58	9.90	9.90	9.70	9.70
	VibraTilt	9.70	9.70	9.80	9.90	9.70	9.80	9.80	9.80	9.40	9.40	10.10	10.10
Accuracy	g Values	98.97	98.97	100.00	98.99	91.94	91.00	92.00	92.00	94.70	94.70	96.06	96.06

Table 16. Accuracy Percentages for the Core Wearable

CORE		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
Acceleration (g's)	GY-91	1.00	1.00	1.00	1.00	0.95	0.95	1.04	1.04	1.00	1.00	1.00	1.00
		9.80	9.80	9.80	9.80	9.31	9.31	10.19	10.19	9.80	9.80	9.80	9.80
	VibraTilt	9.70	9.70	9.90	9.90	9.70	9.80	9.90	9.90	9.50	9.50	10.10	10.10
Accuracy	g Values	98.97	98.97	98.99	98.99	95.98	95.00	97.05	97.05	96.84	96.84	97.03	97.03

Table 17. Accuracy Percentages for the Left Foot Wearable

LEFT FOOT		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
Acceleration (g's)	GY-91	1.00	1.00	1.01	1.01	0.99	0.99	1.01	1.01	1.00	1.00	1.00	1.00
		9.80	9.80	9.90	9.90	9.70	9.70	9.90	9.90	9.80	9.80	9.80	9.80
	VibraTilt	9.70	9.70	9.90	9.80	9.70	9.70	9.80	9.90	9.50	9.40	10.10	10.10
Accuracy	g Values	98.97	98.97	99.98	99.00	99.98	99.98	99.00	99.98	96.84	95.74	97.03	97.03

Table 18. Accuracy Percentages for the Left Arm Wearable

LEFT ARM		POS 1		POS 2		POS 3		POS 4		POS 5		POS 6	
		z-axis				x-axis				y-axis			
		REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2	REP 1	REP 2
Acceleration (g's)	GY-91	1.00	1.00	1.02	1.01	1.01	1.01	0.98	0.98	1.00	1.00	0.99	1.00
		9.80	9.80	10.00	9.90	9.90	9.90	9.60	9.60	9.80	9.80	9.70	9.80
	VibraTilt	9.70	9.70	9.90	9.80	9.70	9.70	9.80	9.80	9.70	9.70	9.90	9.90
Accuracy	g Values	98.97	98.97	99.03	99.00	97.96	97.96	98.00	98.00	98.97	98.97	98.00	98.99

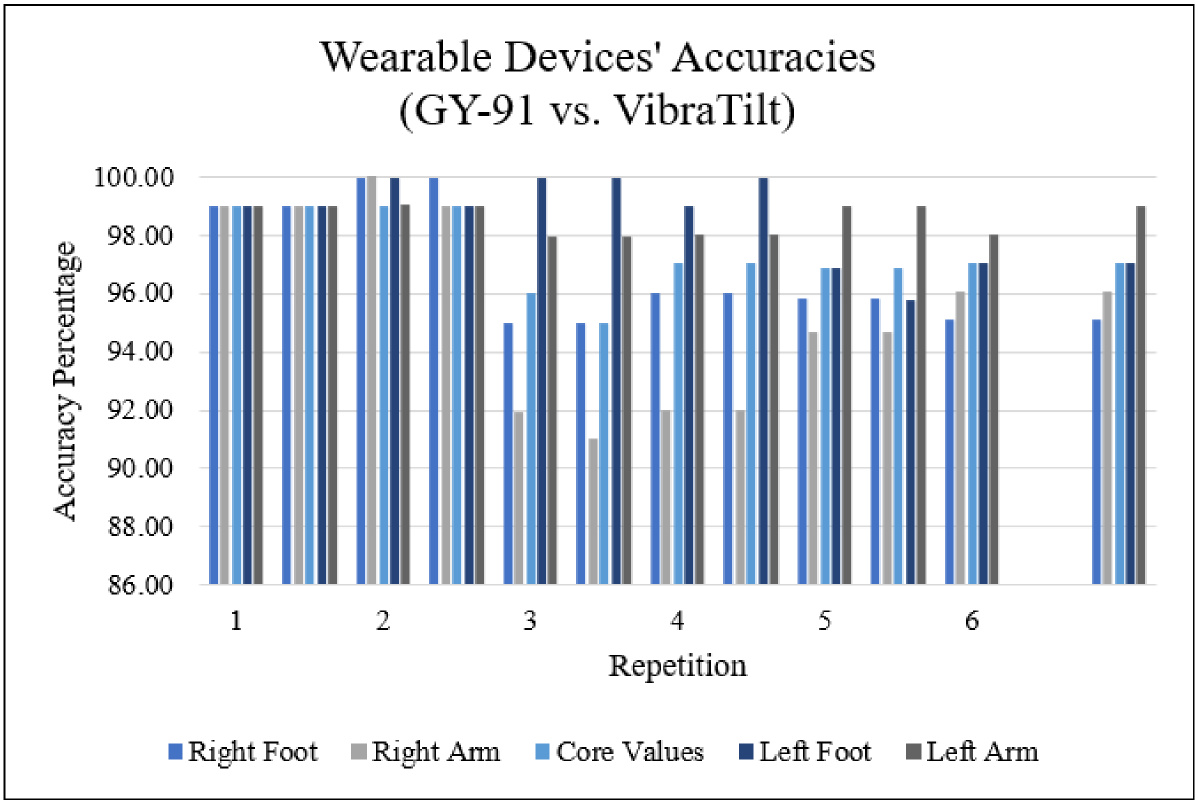


Figure 39. *Wearable Devices' Collective Accuracies (GY-91 vs. VibraTilt)*

The clustered column bar graph above (Figure 39) shows the collective accuracies of all the wearable devices. From this visualization, it can be drawn out that movements in the user's body can change the accuracy level of the devices. Nonetheless, the devices work optimally with the accuracy rating ranging from 91% to 100%.

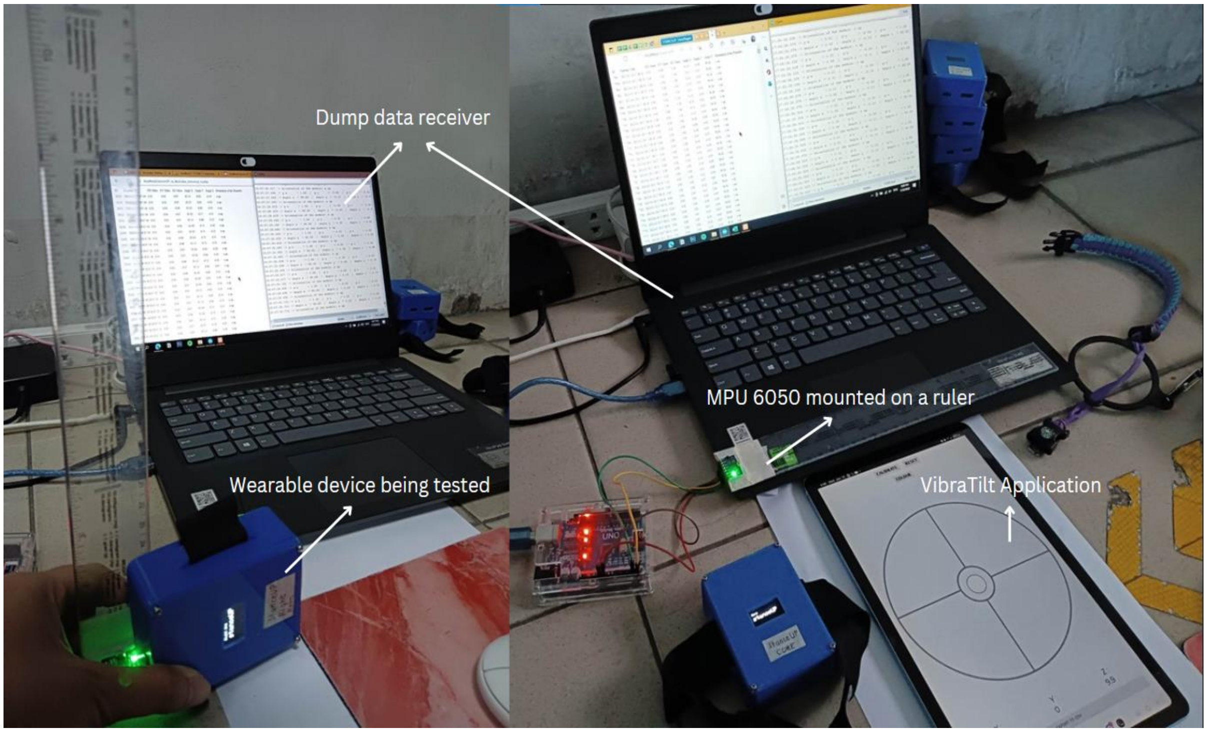


Figure 40. *Calibration and Accuracy Testing using other commercially available IMUs*

Figure 40 shows the calibration and testing done for the wearable devices. The proponents used two commercially available IMUs like MPU-6050 and the ones used in phones through VibraTilt application to determine the accuracy of the developed wearable devices.

4.4.2 Data Consistency

The screenshots below (Figure 41a-b) show the dump data for both the right arm and right foot wearable. The records should show data from a specific timestamp. When these wearable sensors were open for that duration, the recorded data for the right arm pushed out more samples or rows per second in the MySQL database while the recorded data for the right foot pushed out lesser samples or rows per second in the database. The missing rows of data given by the right foot wearable, specifically its

Wi-Fi module, may be potentially caused by signal occlusions in the area where the researchers were testing, and unstable wireless transmission [46].

Database: stanceup_db, Table: ra_imu_sensorlog, Purpose: Dumping data

id	reading_time	gxValue	gyValue	gzValue	AngleXValue	AngleYValue	AngleZValue	orientation
1	2023-05-09 13:45:40	0.55	0.39	0.38	32.96	22.72	22.62	z up
2	2023-05-09 13:45:41	-0.04	0.85	0.52	-1.82	58.78	31.47	y up
3	2023-05-09 13:45:41	1.05	0.72	-1.79	90.00	45.14	-90.00	x up
4	2023-05-09 13:45:41	1.80	0.66	-1.98	90.00	42.27	-90.00	x up
5	2023-05-09 13:45:41	0.36	0.42	-1.01	21.78	25.41	-90.00	z down
6	2023-05-09 13:45:41	0.12	0.41	-0.86	7.01	23.83	-59.13	z down
7	2023-05-09 13:45:41	0.30	0.50	-0.86	17.67	29.79	-59.23	z down
8	2023-05-09 13:45:42	0.25	0.46	-0.88	14.80	27.31	-61.70	z down
9	2023-05-09 13:45:42	0.26	0.43	-0.85	14.89	25.32	-58.48	z down
10	2023-05-09 13:45:42	0.28	0.46	-0.87	16.28	27.14	-60.26	z down
11	2023-05-09 13:45:42	0.28	0.44	-0.87	16.12	26.10	-59.90	z down
12	2023-05-09 13:45:42	0.26	0.45	-0.86	15.26	26.50	-59.30	z down
13	2023-05-09 13:45:42	0.26	0.44	-0.87	15.22	25.88	-60.67	z down
14	2023-05-09 13:45:42	0.25	0.41	-0.87	14.60	24.32	-60.31	z down
15	2023-05-09 13:45:43	0.29	0.45	-0.89	16.94	26.68	-62.72	z down
16	2023-05-09 13:45:43	0.50	0.26	-0.94	30.35	14.37	-69.94	z down
17	2023-05-09 13:45:43	0.83	-1.08	-1.93	55.58	-90.00	-90.00	x up
18	2023-05-09 13:45:43	0.99	0.66	-1.40	80.32	42.44	-90.00	x up
19	2023-05-09 13:45:43	-0.45	0.53	0.56	-26.60	32.53	33.59	z up
20	2023-05-09 13:45:43	0.60	0.17	0.63	37.12	9.46	38.93	z up
21	2023-05-09 13:45:43	0.82	0.14	0.60	55.16	7.92	36.71	x up
22	2023-05-09 13:45:44	0.68	0.13	0.65	42.93	7.21	40.68	z up
23	2023-05-09 13:45:44	0.57	0.21	0.53	34.57	12.17	31.50	z up
24	2023-05-09 13:45:44	0.37	0.39	0.36	21.88	22.78	20.99	z up
25	2023-05-09 13:45:44	1.25	0.15	0.28	90.00	8.86	15.90	x up
26	2023-05-09 13:45:44	0.48	0.80	0.11	28.52	53.61	6.39	y up
27	2023-05-09 13:45:44	0.78	1.09	-0.38	51.26	90.00	-22.26	x up
28	2023-05-09 13:45:45	0.32	1.04	0.08	18.34	90.00	4.72	y up
29	2023-05-09 13:45:45	0.47	0.89	0.04	27.97	62.75	2.37	y up
30	2023-05-09 13:45:45	0.23	1.08	-0.02	13.04	90.00	-1.23	y up

(a) *Dump Data for the Right Arm Wearable.*

Database: stanceup_db, Table: rf_imu_sensorlog, Purpose: Dumping data

id	reading_time	gxValue	gyValue	gzValue	AngleXValue	AngleYValue	AngleZValue	orientation
1	2023-05-09 13:45:45	-0.09	1.09	-0.42	-6.15	90.00	-24.35	y up
2	2023-05-09 13:45:45	-0.05	0.96	-0.33	-2.67	74.24	-19.55	y up
3	2023-05-09 13:45:45	-0.09	0.99	-0.33	-5.19	80.58	-18.94	y up
4	2023-05-09 13:45:45	-0.03	1.00	-0.22	-1.48	90.00	-12.74	y up
5	2023-05-09 13:45:45	0.04	0.93	0.00	2.44	67.82	0.07	y up
6	2023-05-09 13:45:46	-0.02	1.03	-0.14	-1.16	90.00	-8.06	y up
7	2023-05-09 13:45:46	-0.08	1.01	-0.07	-4.53	90.00	-3.79	y up
8	2023-05-09 13:45:46	-0.12	1.02	-0.09	-6.77	90.00	-5.03	y up
9	2023-05-09 13:45:46	-0.16	1.01	-0.07	-8.92	90.00	-4.20	y up
10	2023-05-09 13:45:46	-0.15	1.01	-0.07	-8.63	90.00	-3.96	y up
11	2023-05-09 13:45:47	-0.16	1.02	-0.07	-9.44	90.00	-4.16	y up
12	2023-05-09 13:45:47	-0.15	1.01	-0.09	-8.56	90.00	-4.89	y up
13	2023-05-09 13:45:47	-0.17	1.02	-0.06	-9.69	90.00	-3.71	y up
14	2023-05-09 13:45:48	-0.17	1.01	-0.06	-9.58	90.00	-3.66	y up
15	2023-05-09 13:45:48	-0.16	1.01	-0.07	-9.38	90.00	-3.78	y up
16	2023-05-09 13:45:48	-0.13	1.01	-0.03	-7.43	90.00	-1.68	y up
17	2023-05-09 13:45:48	-0.31	1.06	-0.19	-18.51	90.00	-11.15	y up
18	2023-05-09 13:45:49	-0.16	1.07	-0.20	-9.78	90.00	-11.41	y up
19	2023-05-09 13:45:58	-0.38	0.75	-0.62	-22.45	48.90	-38.25	y up
20	2023-05-09 13:45:58	-0.18	0.98	-0.03	-10.27	76.51	-1.90	y up
21	2023-05-09 13:45:58	-0.11	1.02	0.00	-6.58	90.00	-0.02	y up
22	2023-05-09 13:45:59	-0.16	1.02	-0.07	-9.40	90.00	-3.87	y up
23	2023-05-09 13:45:59	-0.17	1.02	-0.08	-9.72	90.00	-4.50	y up
24	2023-05-09 13:45:59	-0.18	1.02	-0.06	-10.16	90.00	-3.45	y up
25	2023-05-09 13:46:00	-0.14	1.02	-0.05	-8.33	90.00	-2.77	y up
26	2023-05-09 13:46:01	0.02	1.01	-0.10	1.43	90.00	-5.76	y up
27	2023-05-09 13:46:01	-0.12	1.02	-0.10	-6.99	90.00	-5.69	y up
28	2023-05-09 13:46:02	-0.16	1.01	-0.09	-9.36	90.00	-5.22	y up
29	2023-05-09 13:46:03	-0.16	1.01	-0.10	-9.32	90.00	-5.98	y up
30	2023-05-09 13:46:03	-0.16	1.01	-0.10	-9.41	90.00	-5.71	y up

(b) Dump Data for the Right Foot Wearable

Figure 41a-b. *Dump Data from the Wearables*

4.4.3 Weight of the Wearables

Theoretically, the wearables should weigh 96.02g - 101.02g. In actuality, the wearable weight ranges from 100g to 108g (Table 19). There is no basis for the weight of each wearable. The researchers used minimal components and modules to ensure that the overall weight does not cause discomfort to its users. Additionally, the data subjects used for the benchmarking process verified that the weight of the wearables is comfortable nor limiting.

Table 19. Overall Theoretical Weight

COMPONENT	WEIGHT BASED ON SPECIFICATIONS
NODEMCU (Wi-Fi Module)	8g
GY-91 IMU	0.14g
OLED 12C Display	5.98g
Vibration Module	5g
18650 Battery Charger Module	5g
Battery	10.5g
Step-up voltage regulator	0.7g
Casing	32g
Cover	15g
Wires	3.7g
Buckles and Straps	10~15g
Total Weight	**96.02g - 101.02g**

(a) Core

(b) Left Arm

(c) Left Foot

(d) Right Arm

(e) Right Foot

Figure 42a - e. *Actual weight of the wearables*

Figure 42 a-e shows measured weight of the wearables in a weighing scale, which has an average weight of 102.6 grams.

4.4.4 Battery Level

Theoretically, each wearable should be able to continuously function for 3 hours and 3 mins. It can work for 3 hours, which is only a 1.5% error. As for the charging time, with a 1 mA charge rate current, the ideal time should be 30 minutes, but with a 40% efficiency loss, the usual charging time is approximately 40 minutes. The table and computations below explain these values.

Table 20. Total current needed for each wearable.

DEVICE	VOLTAGE	CURRENT
NODEMCU (Wi-Fi Module)	5V	80 mA (during Wi-Fi Operations)
GY-91 IMU	3.3V	3.5 mA (MPU9250) 0.6 mA (BMP280)
OLED 12C Display	3.3V	20 mA
Vibration Module	5V	60 mA
Total Current needed:		**164.1 mA**

To get the hours of operation:

Battery Life = Battery Capacity (in mAh) / Load Capacity (in mA)

Battery Life = 500 mAh / 164.1 mA = **3.047 hours of operation**

And as for the ideal charging time:

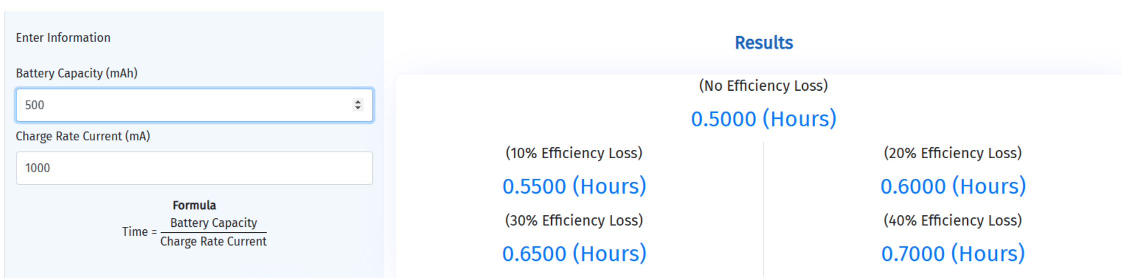


Figure 43. *Charging Time Computation (Source: https://www.calculators.tech/battery-charge-time)*

Figure 43 shows the ideal charging time computation with efficiency loss for the wearable device. As observed, the charging time ranges from 30-45 minutes, and based on the figure showed above, it has an efficiency loss of 30-40%.

4.4.5 Overview of the Dataset for Benchmarking

Table 21. Dataset Summary

Form Name	**Subjects for Benchmark**	**Total movements in one cycle**	**Repetition recorded/per movement**	**Total recorded files**
Taegeuk 1	4	16	3	192
Taegeuk 2	4	18	3	216
Taegeuk 3	4	20	3	240
Taegeuk 4	4	20	3	240
			TOTAL	**888**

Table 21 shows the overview of the dataset for benchmarking, wherein there are four Taegeuk forms gathered from four Taekwondo athletes, with three repetitions of each form. However, since there are various movements per form, the total movements in one cycle and repetition recorded per movement per specific subject is multiplied with each other. Hence, 888 total recorded IMU-XEF pair files for the four Taegeuk levels.

4.4.6 Tabulation of the System Results

The values contained in the tabulated results (Table 22) show the accuracy of the model created for the system. The model was trained only with Taegeuk 1 and its Poomsae Forms, consisting of sixteen movements. Overall, the model achieved an accuracy rate of 70 percent. However, this accuracy rate was found to be inconsistent due to the structure of the input used for training. Improvements to both the model and the extraction of input data are needed to increase this percentage.

Different parameters were given importance when collecting data from the subjects who used the system. A summary of the data subjects' details is as follows: Subject/User A is 5.1 feet tall and weighs 47kg. Subject A has a good background in Taekwondo. Subject/User B is 5.1 feet tall and weighs 42kg. Subject B has beginner-level skills in Taekwondo.

To determine the accuracy of the system's score, the system's output is compared with the conventional scoring method (Table 22 and Figure 44). The conventional scoring process is based on deducting points for mistakes made during the execution of the forms, ranging from minimal to major errors. This conventional scoring is performed by one of the senior athletes in the team.

The data presentations below provide further information about the average percentage error, which emphasizes the need for improving the model. Additional factors that may contribute to this percentage error must be further investigated to enhance the system's accuracy in scoring the athletes' execution.

In addition to the accuracy percentage, another factor that should be considered for further development of the algorithm is the speed of inference. According to the researchers' testing, it takes two minutes for the algorithm to provide a result based on its analysis. However, the speed of the inference process varies depending on the size of the input files.

Table 22. Results in Identifying Accuracy

Data Subject	Movement Done	Expected score via Conventional Scoring (Score/10)	Accuracy using StanceUP	Percent Error
A	Movement five	< .60	.500	20
A	Movement five	> .95	.700	35.71
B	Movement two	< .50	.590	15.25
B	Movement two	> .70	.600	16.67

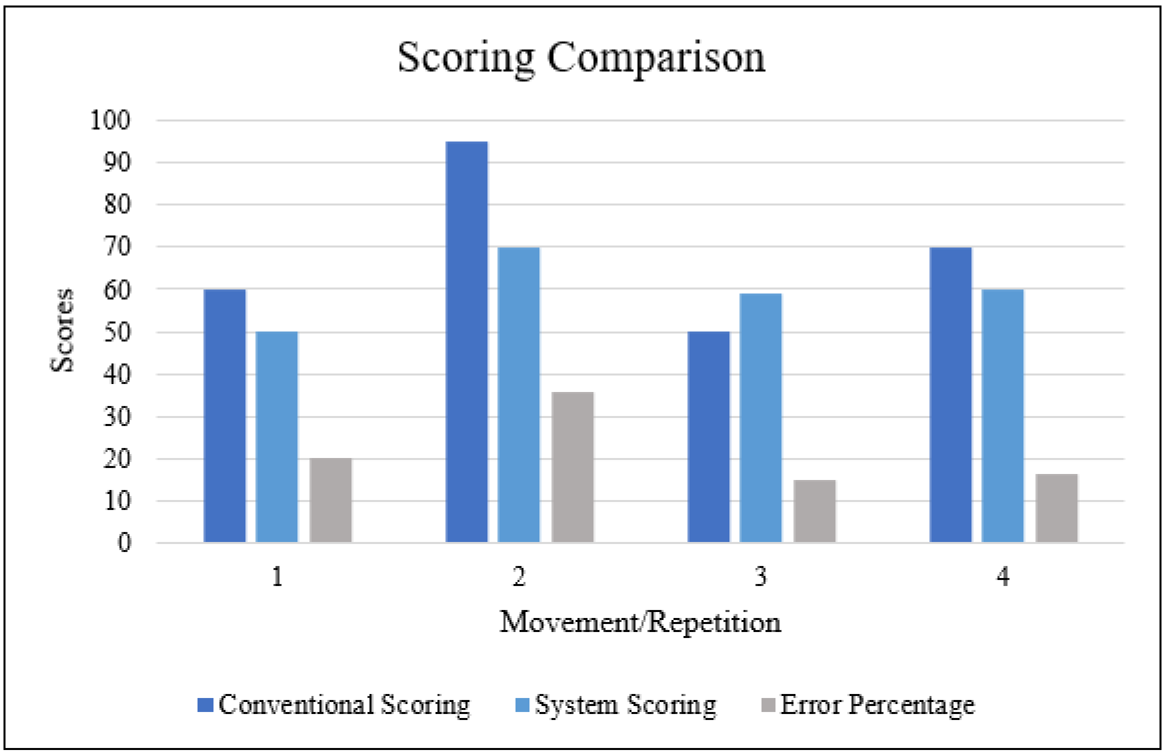


Figure 44. *Scoring Comparison*

4.4.7 Results from the Expert and Stakeholders' Evaluation

The researchers sought the evaluation of Taekwondo coaches, sports professionals, and professionals in the computer science and information technology field.

For the technology field, Prof. Dolores Montesines, the head of the Computer Science department of TUP-Manila, and Prof. Julius Sareno, the head for Information Technology, were the experts consulted. On the other hand, Prof. Allan Soria, the director of the Sports department of TUP-Manila, was consulted about the sports aspect of the study.

For easier tabulation of the evaluation done by the experts, codenames were utilized. Expert A is Prof. Montesines, Expert B is Prof. Sareno, and Expert C is Prof. Soria.

Table 23. Tabulated Summary of Experts' Evaluation

PARAMETER	EXPERT			AVERAGE
	A	**B**	**C**	*(Max: 5.00)*
I. General Impact				**4.78**
1. Novelty of the Project	4	4	5	
2. Impact on the Sports Industry	5	5	5	
3. Effectiveness	5	5	5	
II. System				**4.94**
Hardware Devices				
1. Design and Aesthetics	5	5	5	
2. Functionality	5	5	5	
3. Safety	5	5	5	
4. Ease of Use	5	5	4	
Desktop Application				
1. User-friendliness	5	5	5	
2. Design and Aesthetics	5	5	5	
III. Structural Design				**4.58**
1. Accuracy	4	4	5	
2. Reliability	4	4	5	
3. Maintainability	4	5	5	
4. Portability	5	5	5	

The table above shows the summary of the expert's evaluation under various parameters. For the general impact, it garnered an average score of 4.78 over 5.00, having the highest score in effectiveness and impact to the sports industry. For the system category, the hardware devices gathered an average of 4.917, while the desktop application had an average of five, giving a combined average of 4.94. The structural design of the system scored an average of 4.58 for the categories of accuracy, reliability, maintainability, and portability of the system.

4.4.8 Results from the Users Acceptance Survey

Table 24a-b. General Insights of the Users

GENERAL INSIGHTS				
Question	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**
I am satisfied with both the hardware and software of the training system.	Agree	Agree	Agree	Agree
I am satisfied with the placement and fitting of the wearable sensors.	Agree	Agree	Agree	Strongly Agree
I am satisfied with the current software application user interfaces.	Agree	Agree	Agree	Agree
I believe that the training system will be beneficial to aspiring Taekwondo athletes.	Strongly Agree	Strongly Agree	Agree	Agree
I believe that the training system is efficient and user-friendly.	Agree	Strongly Agree	Agree	Agree
The training system helped me gain more interest in pursuing greater skills in Taekwondo.	Agree	Strongly Agree	Agree	Strongly Agree
For the Taekwondo Athletes, Coaches and Enthusiasts, how did the overall setup make you feel about the whole concept of the training system?	Very Positive	Positive	Very Positive	Very Positive
For the Taekwondo Athletes, Coaches and Enthusiasts, would you be interested in investing in this kind of training system?	YES	YES	YES	YES

(a)

Frequency			
Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
0	0	4	0
0	0	3	1
0	0	4	0
0	0	2	2
0	0	3	1
0	0	2	2
Very Negative	**Negative**	**Positive**	**Very Positive**
0	0	1	3
Yes	**No**	**Maybe**	
4	0	0	

(b)

The first part of the user acceptance survey was to collect the general insights of the participants about the project study. Based on the responses, the users all agreed that they were satisfied with both the hardware and software of the training system, as well as the current software application interface. Moreover, most of the users agreed that they were satisfied with the placement of the wearable devices, and that the training system is efficient and user-friendly. In terms of the beneficial effect of the training system on aspiring Taekwondo athletes and its ability to make users more interested in improving their Taekwondo skills, the responses were positive. They also felt positive about the concept of the training system. Lastly, the users felt interested in investing in this kind of training system.

Table 25a-m. Summary of User Evaluation based on ISO 9126 and ISO/TC 83

LIKERT SCALE PORTION						
Criteria	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Total Average**	**Interpretation**
I. FUNCTIONALITY	3.60	3.40	4.00	4.00	3.75	Positive
II. EFFECTIVENESS	3.60	3.20	3.80	4.40	3.75	Positive
III. RELIABILITY	3.80	3.80	4.20	4.60	4.10	Positive
IV. SECURITY	3.80	3.80	3.80	4.40	3.95	Positive
V. PERFORMANCE	3.80	3.80	4.20	4.20	4.00	Positive
VI. COMPATIBILITY	4.67	4.67	5.00	5.00	4.83	Positive
VII. MAINTAINABILITY	5.00	5.00	4.67	5.00	4.92	Positive
VIII. PORTABILITY	4.00	4.00	3.50	3.50	3.75	Positive
IX. SCALABILITY	3.80	3.80	3.80	4.00	3.85	Positive
X. ACCESSIBILITY	4.40	4.20	4.40	4.00	4.25	Positive
XI. SUPPORT	4.40	4.00	4.40	3.80	4.15	Positive
XII. USABILITY	4.20	4.00	4.40	4.00	4.15	Positive

(a) Summary of User Evaluation per Criteria

LIKERT SCALE PORTION						
Question	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Average**	**Interpretation**
I. FUNCTIONALITY						
The wearable device accurately tracked my movements during training sessions.	5	5	5	4	4.75	Positive
The Kinect sensor provided clear and complete footage of my training sessions.	5	4	5	4	4.5	Positive
The desktop application provided helpful insights and recommendations based on my training data.	3	2	3	4	3	Neutral
The system provided accurate and reliable data for me to analyze my performance.	3	3	4	4	3.5	Positive
The system helped me identify areas of weakness and suggested exercises to improve them.	2	3	3	4	3	Neutral

(b) Likert Scale Results for Functionality

II. EFFECTIVENESS						
The system helped me improve my athletic performance.	5	4	4	5	4.5	Positive
The system helped me identify areas of improvement in my training.	3	3	3	4	3.25	Neutral
The system provided helpful feedback on my technique and form during exercises.	3	3	4	4	3.5	Positive
The system helped me set and achieve specific goals in my training.	3	2	3	4	3	Neutral
The system helped me stay motivated and engaged in my training program.	4	4	5	5	4.5	Positive

(c) Likert Scale Results for Effectiveness

III. RELIABILITY						
The system was consistent and reliable during my training sessions.	4	4	4	5	4.25	Positive
The system did not experience frequent crashes or technical issues.	3	3	4	4	3.5	Positive
The system provided accurate and reliable data over an extended period of time.	4	4	4	5	4.25	Positive
The system was able to recover from technical issues or interruptions quickly.	3	3	4	4	3.5	Positive
The system was able to function in a variety of different training environments and conditions.	5	5	5	5	5	Positive

(d) Likert Scale Results for Reliability

IV. SECURITY						
The system provided adequate protection of my personal data and information.	4	4	4	5	4.25	Positive
The system provided secure access to my training data and information.	4	4	4	5	4.25	Positive
The system provided clear information about how my data was being used and stored.	4	4	3	4	3.75	Positive
The system had measures in place to prevent unauthorized access to my data.	4	4	5	4	4.25	Positive
The system had measures in place to prevent data loss or corruption.	3	3	3	4	3.25	Neutral

(e) Likert Scale Results for Security

V. PERFORMANCE						
The system provided accurate and timely feedback during my training sessions.	4	4	5	5	4.5	Positive
The system was able to handle large amounts of data without slowing down or crashing	4	3	4	4	3.75	Positive
The system was able to provide real-time analysis and recommendations based on my training data	3	4	4	4	3.75	Positive
The system helped me track my progress over time.	5	5	5	4	4.75	Positive
The system was able to adapt to changes in my training program or goals.	3	3	3	4	3.25	Neutral

(f) Likert Scale Results for Performance

VI. COMPATIBILITY						
The application worked seamlessly with the wearable devices I used.	5	4	5	5	4.75	Positive
The application worked seamlessly with the Kinect sensor I used.	5	5	5	5	5	Positive
The application worked seamlessly with my computer's operating system.	4	5	5	5	4.75	Positive

(g) Likert Scale Results for Compatibility

VII. MAINTAINABILITY						
The wearable devices were easy to store.	5	5	4	5	4.75	Positive
The Kinect sensor was easy to keep.	5	5	5	5	5	Positive
The instructions provided for maintenance of the hardware devices were clear and helpful.	5	5	5	5	5	Positive

(h) Likert Scale Results for Maintainability

VIII. PORTABILITY						
The hardware system was easy to transport and set up in different training environments.	4	4	3	4	3.75	Positive
The application was easy to install in my computer.	4	4	4	3	3.75	Positive

(i) Likert Scale Results for Portability

IX. SCALABILITY						
The system was able to handle an increasing amount of data without slowing down or crashing.	3	4	3	4	3.5	Positive
The system was able to scale up or down depending on changing needs or requirements.	3	3	3	4	3.25	Neutral
The system was able to handle a large number of data from different users in one device without sacrificing performance or functionality.	4	4	4	4	4	Positive
The system was designed in a way that made it easy to add new features or functionality as needed.	5	4	4	4	4.25	Positive
The system was designed in a way that made it easy to integrate with other systems or tools.	4	4	5	4	4.25	Positive

(j) Likert Scale Results for Scalability

X. ACCESSIBILITY						
The system was designed in a way that made it accessible to athletes with different abilities or disabilities	4	5	5	4	4.5	Positive
The system provided clear and helpful instructions for athletes who may require additional support or accommodation	5	5	5	4	4.75	Positive
The system provided a variety of features or tools to help athletes with different needs or requirements.	5	4	5	4	4.5	Positive
The system provided clear and helpful feedback to athletes with different learning styles or preferences	4	4	4	4	4	Positive
The system was designed in a way that made it easy for athletes to customize settings or preferences to meet their needs.	4	3	3	4	3.5	Positive

(k) Likert Scale Results for Accessibility

XI. SUPPORT						
The system provided clear and helpful documentation and resources.	4	5	5	4	4.5	Positive
The system provided prompt and helpful support in the event of technical issues or questions.	4	4	4	3	3.75	Positive
The system provided a variety of support channels, such as phone, email, or chat.	4	2	3	4	3.25	Neutral
The system provided helpful tutorials or training resources to help me get started.	5	4	5	4	4.5	Positive
The system had a helpful and knowledgeable support team available to assist me.	5	5	5	4	4.75	Positive

(l) Likert Scale Results for Support

XII. USABILITY						
The wearable device was comfortable to wear during training sessions.	3	4	4	4	3.75	Positive
The camera was easy to set up and use during training sessions.	4	4	4	4	4	Positive
The desktop application was easy to navigate and use.	5	4	5	4	4.5	Positive
The system provided clear instructions on how to use the different components.	5	5	5	4	4.75	Positive
The system was easy to learn and use, even for someone with limited technology experience.	4	3	4	4	3.75	Positive

(m) Likert Scale Results for Usability

In terms of the system's reliability, responses show that the users agree that the system can perform the tasks it was designed to do. However, they felt neutral towards the ability of the desktop application to provide helpful insights and recommendations based on the results of the conducted training sessions. Regarding its effectiveness, the users agreed that the system can improve their productivity and performance except for some aspects such as the system's capability to specifically point out the areas that need improvement to help them set their goals in training. Next, the system's reliability received positive feedback, indicating that it can perform consistently over time and under different usage scenarios. The security of the system also received a positive response except for the fact that the users were neutral on the system's ability to prevent data corruption. Regarding the performance of the system, the participants agreed that it can quickly respond to user input and deliver results. However, they were neutral on the system's capability to adapt to changes in their training program. On the other hand, the users showed positive feedback on the system's compatibility, maintainability, and portability. In terms of its scalability, the users agreed that it can oversee more tasks at once. Regarding the system's support, although the need for support channels in the application was raised, they agreed that the documentation provided was helpful. Lastly, the system's usability received a positive response from the users, indicating that it is easy to use and navigate.

4.4.9 Overall Performance

Overall, the system has 50-70% total accuracy in its ability to provide numerical scoring for each Poomsae form execution. In comparison to the conventional process of scoring Poomsae, it needs improvements for it to be more stable and dependable. As for the evaluations for the solution, both the users and the experts saw the importance for the system to exist, and how it affects the training of the athletes and aspiring Taekwondo athletes.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter 5 presents the summary of the study and conclusions drawn based on the results obtained after a series of calibration, testing, and deployment. Additionally, it presents recommendations for further project improvement.

5.1 Summary of Findings

The project Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN) is a study that integrates hardware devices and software whose core system is to train beginner athletes in poomsae execution using CNN model.

The study was successful in creating a system that monitors and gathers posture parameters using information from wearable devices and Kinect camera. The system was able to apply database system for data management and is utilized for training and tracking.

The IMU module was compared and tested with other Inertial movement devices such as MPU - 6050 and VibraTilt application for smartphones. It shows that it has 100% accuracy except for one instance with 91% accuracy due to the unleveled and uncalibrated placement of both the wearable and IMU and it is not properly calibrated.

To categorize the combined visual and sensor data, the study used the combination of CNN and RNN (Recurrent Neural Networks) layers. Contrary to the previously stated method in the objectives, the researchers used a new neural network combination as it was more compatible with the numeric and visual data of the system. Using this combined method, Taekwondo Poomsae training could be monitored, and posture detection could be done with accuracy. The models worked well at understanding and capturing the intricate positions and movements used in training, but still need improvements to achieve higher accuracy.

The user and expert evaluations were conducted in accordance with ISO/TC 83 and ISO 9126, The evaluations and analysis gave insightful information about the produced system's usability, functionality, and general performance. Positive reviews of the system suggest that it has the potential to be used successfully in training settings.

There are some challenges faced with the usage of Kinect as the primary camera sensor. Throughout the investigation, it presented a number of difficulties in terms of compatibility and documentation. Despite these difficulties, the study was able to get beyond them and get acceptable results.

5.2 Conclusions

Based on the results of the benchmarking and deployment of the project, the following conclusions were drawn out by the researchers:

1. Using the combination of data from Kinect and the wearable devices, this study has developed a system that will monitor and collect posture parameters that are vital for the main purpose of this study.
2. The developed desktop application features the training and tracking of athletes through the database system integrated. In total, there are 105 frames for the desktop application.
3. The developed identifying model which utilizes CNN Model in classifying the combined visual and sensor data to properly create a training model was achieved. The highest accuracy that the system achieved is 70% and ranges from 50% to 70%.

4. User and expert evaluations were also conducted, anchored with international standards, ISO/TC 83, and ISO 9126. Users generally provided ‘Very Positive’ feedback on the concept and 'Positive to Neutral' feedback on the actual implementation. Expert evaluations rated the system at 4.67 out of 5 for the various parameters considered.
5. Problems faced throughout the study are due to the utilization of Kinect as the main camera sensor. Technologies.

5.3 Recommendations

The project study was successfully completed; however, due to the weaknesses unveiled in the results, the proponents would like to make the following recommendations to the future researchers:

1. Utilize the Azure Kinect, the latest version of the camera sensor, to lessen the problems faced due to outdated and scarce libraries and documentation compatibility.
2. Decrease the size and weight of the wearables. If possible, integrate the sensors/modules in the training garments/accessories of the athletes.
3. Utilize the haptic indicators inside the wearables more effectively and fully to ensure that the wearables were placed in the right position.
4. Improve the model to enable real-time analysis.
5. Apply a user-focused recommendation system for training/exercise program based on the historical data compiled.
6. Provide support channels in the application.
7. Generate general reports, ones that are printable or can be saved as another file, for easier access to players’ improvements.
8. Used cloud for storing data and progress.

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Appendix A

Deployment Information

APPENDIX A: DEPLOYMENT INFORMATION

Rationale: Taekwondo is a sport that can offer a range of benefits to university students, including stress relief, self-defense skills, discipline, and teamwork. Therefore, establishing a university taekwondo team would be an excellent way to promote these benefits to students and provide them with a platform to highlight their athletic abilities.

The TUP Taekwondo Team participates in different intercollegiate competitions. Through the years, they have won awards that boosted the morale of the university, however, lack of coaches and training systems especially for Poomsae have made the researchers choose this team for the deployment of their project. Other reasons that would support this decision are as follows:

- Location was chosen because of convenience.
- Future development and goals of the university in Sports Engineering
- Beneficial for increasing the performance of the university in terms of Taekwondo.

Location:

- TUP Manila (Main Campus)
  - Address: San Marcelino St, Ayala Blvd, Ermita, Manila, 1000
- Contact Person:
  - Mr. Allan Soria - Director, Sports, and Development
  - Mr. Dominic Balajadia - Coach, TUP Taekwondo Team
- People Needed:
  - Technological University of the Philippines - Taekwondo Poomsae Team

Dates of Deployment and Testing: Parts of May and June 2023 (Schedule was based on the availability of the athletes)

Data Gathered During Deployment:

- IMU (Angular, Velocity, Orientation)
- Kinect data (Streams like Depth, IR, Calibration data, Sensor Telemetry, Body Frame, Body Index, Opaque Data, Long Exposure IR)
- Data will be collected from the TUP Taekwondo Athletes
- The data will be gathered from the Athletes by getting them to perform the Taekwondo Taegeuk Forms using the system.

Data Gathering Procedure – Setting Up the System:

- Open the wearables on a flat surface. The wearables will calibrate for a few seconds.
- Check if the wearables can send data to the database.
- After calibration, place the wearables in your body. An example image is shown on the software application.
- Open the Kinect Camera through connecting various cords. Open the Microsoft Kinect SDK to secure its placement in your training area.

Data Gathering Procedure – Data acquisition:

- Participating athletes must perform all the Poomsae Forms of Taegeuk Levels 1 to 4 continuously and by movement with three repetitions each.

COVID-19 Safety Protocols during the Deployment: In line with the COVID 19, the following should be strictly observed during the deployment and data gathering period due to justifiable reasons:

Policies that must be observed during the data gathering sessions:

- readily available alcohol-dispensers, tissues, and trash receptacles
- respiratory etiquette (such as covering coughs and sneezes)

- disinfection and routine cleaning of the frequently-touch surfaces/objects (such as the wearables, the tables, chairs, etc.)
- disinfection of the site
- proper disposal of any waste used during the deployment.
- strict compliance to the IATF protocols (such as wearing of face mask and social distancing) throughout the whole duration.
- individuals should be verified to be fully vaccinated prior to the sessions.

Prohibited risk factors in the deployment area:

- Spitting
- Smoking/Vaping

Confirmed cases detected and compliance:

- deployment site must be reported immediately.
- abide by DOH contract tracing protocols.

Responsibilities: The following are the specific responsibilities of the participants and the researchers for the data gathering sessions that will be conducted:

1. **Participants:**
    - **a.** Participant must have/ must comply:
        - **i.** Sufficient identification (vaccination card, ID)
        - **ii.** Face masks
        - **iii.** Temperature check
        - **iv.** Accomplished student waiver form and health declaration form
    - **b.** After completion/accomplishment of the user training and system testing, participants must leave the University/deployment site premises immediately.

c. Avoid loitering before and after your designated training schedule.

d. If the participant has any symptoms of COVID-19 before the schedule, he/she should inform the researchers immediately.

e. If the participant has any symptoms of COVID-19 during the schedule, he/she will be endorsed to TUP clinic for isolation. Other participants with contact with the affected participant will be requested to remain on the deployment site and wait for further announcement.

2. Researchers

a. Researchers must make sure that the deployment site (and the components of the deployed project) must be disinfected before and after each data gathering session.

b. They should be flexible in scheduling, especially in cases where the participant informed them of having symptoms.

c. In instances that there are confirmed cases detected, they must be one of the first people to notify/report about this and should provide all the details needed for contact tracing.

d. The researchers must be the main people to encourage the observation of the safety guidelines.

Appendix B

Deployment Implementation

APPENDIX B: DEPLOYMENT IMPLEMENTATION

TECHNOLOGICAL UNIVERSITYOF THE PHILIPPINES
Ayala Boulevard, Ermita, Manila
COLLEGE OF ENGINEERING
Electronics Engineering Department

DEPLOYMENT IMPLEMENTATION PLAN

Thesis Title: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

Proponents: Emmanuel Kenneth R. Bernas, Samantha Nicole S. Cabrera, Mc Katherine P. Cuya, Joweena Patricia P. David, & Gem Nicole A. Garufil

Target Date: 2^{nd} or 3^{rd} week of July 2023

I. Introduction

This document serves as a comprehensive guide for the deployment implementation plan of the StanceUP system. It outlines the purpose, scope, and key details necessary to facilitate a successful deployment process. By providing the reader with essential information, this document aims to orient and guide stakeholders involved in the deployment of the StanceUP system.

The deployment implementation plan encompasses the various stages, tasks, and considerations required to ensure a smooth and effective deployment process. It outlines the steps to be taken, the roles and responsibilities of team members, and the timelines associated with each phase.

Throughout this document, you will find detailed explanations of the deployment objectives, strategies, and methodologies. It will address the training needs of personnel, the technical requirements for system installation, and the considerations for data migration and integration.

Additionally, this document will provide insights into the evaluation and monitoring processes employed during the deployment. It will highlight the importance of gathering feedback, conducting assessments, and tracking the progress of the deployment to ensure that objectives are met and challenges are addressed promptly.

By following this deployment implementation plan, stakeholders will gain a comprehensive understanding of the tasks at hand and the necessary steps to achieve a successful deployment of the StanceUP system.

II. Stakeholders

The TUP Taekwondo Team participates in different intercollegiate competitions. Through the years, they have won awards that boosted the morale of the university, however, lack of coaches and training systems especially for Poomsae have made the researchers choose this team for the deployment of their project. Other reasons that would support this decision are as follows:

- Location was chosen because of convenience.
- Future development and goals of the university in Sports Engineering
- Beneficial for increasing the performance of the university in terms of Taekwondo.

Location:

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- People Needed:
  - Technological University of the Philippines - Taekwondo Poomsae Team

Dates of Deployment and Testing: Parts of May and June 2023 (Schedule was based on the availability of the athletes)

III. Training Proper

a. Overview

This personnel training session is an integral part of the implementation plan for deploying the StanceUP system to the TUP-Manila Taekwondo team. The total deployment is scheduled for July-August 2023 and it is crucial that this training is conducted one week prior which is probably any day on the 2nd or 3rd week of July. The training will take place in a designated room for Taekwondo athletes' practices.

The objective of this personnel training is to ensure that once the StanceUP system is deployed and transferred to the team, they possess the necessary skills and expertise to effectively utilize, oversee, and maintain the system. By providing comprehensive training, we aim to eliminate the need for constant intervention from the system proponents throughout the entire implementation period.

b. Training Needs

<table>
<tr><th>Personnel to be Trained</th><th>Required Competencies</th></tr>
<tr><td>Coach Gilbert Balajadia and Coach Rochelle Arevalo</td><td rowspan="3">Technical Skills in setting up and doing basic maintenance and troubleshooting.

Communication and teaching abilities for conveying important system knowledge

Leadership skills for initiating training sessions using the developed system

Must be knowledgeable in Taegeuk and Poomsae</td></tr>
<tr><td>Prof. Allan D. Soria</td></tr>
<tr><td>Taekwondo - Poomsae Team Captain</td></tr>
</table>

c. Program Flow

TIME	*ACTIVITY*
8:00 – 10:00 am	*Preparation of the Area* • *Initial setup of the system* • *Disinfection of the area and system*
10:00 - 10:30 am	*Ingress* • *Welcome Remarks* • *Doxology* • *National Anthem*
10:30 - 11:00 am	*Brief introduction to the project and the team*
11:00 - 11:30 am	*Introducing the contents of MOA & NDA*
11:30 - 12:00 pm	*Signing of the agreements*
LUNCH BREAK	
1:00 - 2:00 pm	*Topic 1: Setup, use, storage process*
2:00 - 3:00 pm	*Topic 2: Maintenance & Troubleshooting*
3:00 - 4:00 pm	*Sample Testing and Demonstration*
4:00 - 4:15 pm	*Proper Turnover and Photo Opportunity*
4:15 - 4:30 pm	• *Closing Remarks* • *TUP Hymn* *Egress*
4:30 - 5:00 pm	*Area Clean up and Disinfection*

IV. Feedback and Assessment`

a. Training Evaluation

Consists of criteria that will evaluate the personnel/s knowledge about the training system.

Percentage	***Objective*/Competencies achieved**
50%	Basic Setup of the system to the training environment
15%	Proper Setup of the wearable system to the body of the athlete
20%	Basic Troubleshooting (Hardware and Software)
10%	Maintenance Checking Process
5%	Further precautions

b. Monitoring & Reporting

Reports should be tracked by:

- Essay simulation of how-to setup the system and other considerations in using the system
- Weekly performance of the system in comparison to conventional process
- Monthly accomplishment of preventive maintenance form and system checklist
- Sending of portfolio containing documentation pictures and score sheets of student athletes

Appendix C

Turn-over Letter

APPENDIX C: TURN-OVER LETTER

Republic of the Philippines
Technological University of the Philippines
COLLEGE OF ENGINEERING
Ayala Blvd., corner San Marcelino St., Ermita, 1000 Manila
Fax: (63-2) 521-4063, Tel. Nos. (63-2) 523-2293, Trunkline: 302-7750 loc. 112
Website: http://www.tup.edu.ph

July 06, 2023

Engr. Jay Fel C. Quijano
Research Adviser and Faculty Member
Electronics Engineering Department
College of Engineering

RE: Project Turn Over to the Research Adviser

Dear Sir,

We hope this letter finds you in good health and high spirits. We are writing to inform you that the College of Engineering - Electronics Department intends to deploy our study titled **"Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)"** within the Sport Development Office.

As part of our academic research, our team has developed a system that combines advanced technologies such as Kinect and IMU sensors with Convolutional Neural Networks (CNN) to facilitate the detection and monitoring of postures during the beginner level training of Taekwondo Poomsae. The primary objective of this study is to enhance the training experience of Taekwondo enthusiasts and assist them in improving their technique and performance.

We have chosen the Sport Development Office as the deployment area for our study due to its active involvement in fostering sports improvement and its commitment to promoting new and innovative training methods. With the deployment of our system, we aim to provide a valuable tool to both coaches and beginners in the field of Taekwondo. The system will enable posture detection and monitoring, providing feedback and guidance to users, ultimately enhancing their learning and progression.

Should you have any questions or require further information about our study, please do not hesitate to contact us. We would be more than happy to provide any additional details or arrange a meeting to discuss the deployment in more depth.

Thank you for considering our request. We believe that our study has the potential to revolutionize beginner level training in Taekwondo and contribute significantly to the sport's development. We look forward to your positive response and the opportunity to collaborate with the Sports Development Office.

Republic of the Philippines
Technological University of the Philippines
COLLEGE OF ENGINEERING
Ayala Blvd., corner San Marcelino St., Ermita, 1000 Manila
Fax: (63-2) 521-4063, Tel. Nos. (63-2) 523-2293, Trunkline: 302-7750 loc. 112
Website: ***http://www.tup.edu.ph***

Technologies for Turnover Checklist:

Quantities	Item	Status/Condition
5	Wearable Devices	Working
1	Kinect Sensor	Working
1	Kinect Adapter and Wiring System	Working
1	Tripod	Good
1	SD Card with System Codes and Software Application	Working
1	Type-C Charger	Good
1	Micro USB Cable	Good
1	Pocket Wi-Fi	Working
1	Storage Box	Good
1	User Manual	Good
1	Manual for Duplication	Good

Respectfully yours,

Ms. Gem Nicole Garufil
Project Lead, ML Model Developer

Ms. Joweena Patricia David
Software Application Developer

Ms. Samantha Nicole Cabrera
Pre-processing ML Model Developer

Mr. Emmanuel Kenneth Bernas
UX and External Affairs Lead

Ms. Mc Katherine Cuya
Hardware Developer

Noted by:

Engr. Timothy M. Amado
Head, Electronics Engineering Department

Engr. Nilo M. Arago
Dean, College of Engineering

Appendix D

Research Waiver

APPENDIX D: RESEARCH WAIVER

	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Ayala Blvd., Ermita, Manila, 1000, Philippines Tel No. +632-301-3001 local 711 | Fax No. +632-521-4063 Email: urds@tup.edu.ph | Website: www.tup.edu.ph	Index No.	F-URD-4.1-RWW
		Issue No.	01
		Revision No.	01
		Date	09212018
VRE-URD	RESEARCH WAIVER AND WARRANTY	Page	1 / 2
		QAC No.	CC-09212018

I/we ***Emmanuel Kenneth R. Bernas, Samantha Nicole S. Cabrera, Mc Katherine P. Cuya, Joweena Patricia P. David, Gem Nicole A. Garufil, & Engr. Jay Fel C. Quijano***

the author(s) of the research paper entitled ***Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)*** is ___ presenting / ✓ publishing the above paper in the

In submitting the above-mentioned manuscript, I/we certify that the said research is:
(Please check all applicable claims).

[✓] An original creation of the Author(s); it has not been presented in other fora, conferences, and conventions; it is not under publication elsewhere in any print/electronic journal/book.
[_] A University Research and Extension Council (UREC) - approved research work.
[_] For topic as an invited resource person or guest speaker.
[_] For presentation as accepted faculty research output.
[✓] A faculty-led research work with authorization from the students-proponent(s) to use this research. Please attach an authorization letter from the students.
[_] A dissertation/thesis of the author of the graduate study program.
[✓] A thesis of the author of the undergraduate program.
[_] A collaborative study with other faculty member(s) in the university, with consent from the co-author(s) to use the research for presentation/publication.
[_] An output of faculty research externally-funded by other agency. (Please attach MOA/MUO as supporting document).
[✓] Contains nothing that is unlawful, libelous, or which would, if presented/published will damage the reputation of the Technological University of the Philippines (TUP).

I/we am/are also aware that if I/we fail to submit the printed and soft copy of the research manuscript for TUP Research Profiling purposes would mean pending processing of my/our request.

AUTHOR(S) FULL NAME AND SIGNATURE:

Author 1:	Emmanuel Kenneth R. Bernas	Author 6:	Engr. Jay Fel C. Quijano
Author 2:	Samantha Nicole S. Cabrera	Author 7:	
Author 3:	Mc Katherine P. Cuya	Author 8:	
Author 4:	Joweena Patricia P. David	Author 9:	
Author 5:	Gem Nicole A. Garufil	Author 10:	

ATTESTED BY:

College Research Coordinator | Immediate Supervisor | College Dean/Director

Transaction ID	
Signature	

Appendix E

Evaluations: Users' Evaluation and Experts' Evaluation

APPENDIX E: USERS' AND EXPERTS' EVALUATION

User's Evaluation

StanceUP
YOU CAN DO GREAT AND BE GREAT

PROJECT TITLE: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

USER ACCEPTANCE AND EVALUATION FORM

Instruction: This form serves as an assessment tool evaluating your experience using the StanceUP training system. Rest assured that all your answers will be safe and secure.

The RA 10173, or the Data Privacy Act, protects individuals from unauthorized processing of personal information that is (1) private, not publicly available; and (2) identifiable, where the identity of the individual is apparent either through direct attribution or when put together with other available information. I hereby authorize the researchers to collect and process the data indicated herein.

[ ] I agree and accept the Data Privacy Agreement.

Name (Optional): Camille Andrea Fabella **Date: June 12,2023**
Current Profession: [ ] Taekwondo Coach [√] Taekwondo Athlete [ ] Other: ____________________

Were you able to see the **whole setup** of the training system? [√] YES [ ] NO

GENERAL INSIGHTS ABOUT THE SETUP OF THE STANCEUP

[Kindly check the corresponding square bracket to your answer]

1. I am satisfied with both the hardware and software of the training system.
[ ] Strongly Agree [√] Agree
[ ] Disagree [ ] Strongly Disagree
2. I am satisfied with the placement and fitting of the wearable sensors.
[ ] Strongly Agree [√] Agree
[ ] Disagree [] Strongly Disagree
3. I am satisfied with the current software application user interfaces.
[ ] Strongly Agree [√] Agree
[ ] Disagree [ ] Strongly Disagree
4. I believe that the training system will be beneficial to aspiring Taekwondo athletes.
[ ] Strongly Agree [√] Agree
[ ] Disagree [] Strongly Disagree
5. I believe that the training system is efficient and user-friendly.
[ ] Strongly Agree [√] Agree
[ ] Disagree [ ] Strongly Disagree
6. The training system helped me gain more interest in pursuing greater skills in Taekwondo.
[ ] Strongly Agree [√] Agree
[ ] Disagree [ ] Strongly Disagree

For the Taekwondo Athletes, Coaches, and Enthusiasts, how did the overall setup make you feel about the whole concept of the training system?
[√] Very Positive [ ] Positive
[ ] Negative [ ] Very Negative

For the Taekwondo Athletes, Coaches and Enthusiasts, would you be interested in investing in this kind of training system?
[√] YES [ ] NO [ ] MAYBE

What do you **like** the most about the training system?
____
____

What do you **dislike** the most about the training system?
____
____

How could the researchers improve the **wearable sensors?**
____
____

How could the researchers improve the **desktop and web applications?**
____
____

StanceUP
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LIKERT SCALE PORTION

[Circle your numeric response to each question]

#	Question	Survey Scale: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree
I. Functionality *[Does the system perform the tasks it was designed to do? Does it have all the necessary features and capabilities?]*		
1	The wearable device accurately tracked my movements during training sessions.	1 2 3 4 5
2	The Kinect sensor provided clear and complete footage of my training sessions.	1 2 3 4 5
3	The desktop application provided helpful insights and recommendations based on my training data.	1 2 3 4 5
4	The system provided accurate and reliable data for me to analyze my performance.	1 2 3 4 5
5	The system helped me identify areas of weakness and suggested exercises to improve them.	1 2 3 4 5
II. Effectiveness *[Does the system meet the user's goals and expectations? Does it improve the user's productivity or performance?]*		
6	The system helped me improve my athletic performance.	1 2 3 4 5
7	The system helped me identify areas of improvement in my training.	1 2 3 4 5
8	The system provided helpful feedback on my technique and form during exercises.	1 2 3 4 5
9	The system helped me set and achieve specific goals in my training.	1 2 3 4 5
10	The system helped me stay motivated and engaged in my training program.	1 2 3 4 5
III. Reliability *[Is the system stable and consistent? Does it perform consistently over time and under different usage scenarios?]*		
11	The system was consistent and reliable during my training sessions.	1 2 3 4 5
12	The system did not experience frequent crashes or technical issues.	1 2 3 4 5
13	The system provided accurate and reliable data over an extended period of time.	1 2 3 4 5
14	The system was able to recover from technical issues or interruptions quickly.	1 2 3 4 5
15	The system was able to function in a variety of different training environments and conditions.	1 2 3 4 5
IV. Security *[Is the system secure and protected from unauthorized access? Does it protect user data and privacy?]*		
16	The system provided adequate protection of my personal data and information.	1 2 3 4 5
17	The system provided secure access to my training data and information.	1 2 3 4 5
18	The system provided clear information about how my data was being used and stored.	1 2 3 4 5

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19	The system had measures in place to prevent unauthorized access to my data.	1 2 3 4 5
20	The system had measures in place to prevent data loss or corruption.	1 2 3 4 5
V. Performance *[Does the system respond quickly to user input and deliver results in a timely manner? Does it perform well under different usage scenarios?]*		
21	The system provided accurate and timely feedback during my training sessions.	1 2 3 4 5
22	The system was able to handle large amounts of data without slowing down or crashing.	1 2 3 4 5
23	The system was able to provide real-time analysis and recommendations based on my training data.	1 2 3 4 5
24	The system helped me track my progress over time.	1 2 3 4 5
25	The system was able to adapt to changes in my training program or goals.	1 2 3 4 5
VI. Compatibility *[Does the desktop application work well with the different devices needed for the system?]*		
26	The application worked seamlessly with the wearable devices I used.	1 2 3 4 5
27	The application worked seamlessly with the Kinect sensor I used.	1 2 3 4 5
28	The application worked seamlessly with my computer's operating system.	1 2 3 4 5
VII. Maintainability *[Are the wearables and Kinect easy to keep and maintain?]*		
29	The wearable devices were easy to store.	1 2 3 4 5
30	The Kinect sensor was easy to keep.	1 2 3 4 5
31	The instructions provided for maintenance of the hardware devices were clear and helpful.	1 2 3 4 5
VIII. Portability *[Can the system be easily moved or installed on different devices and platforms?]*		
32	The hardware system was easy to transport and set up in different training environments.	1 2 3 4 5
33	The application was easy to install on my computer.	1 2 3 4 5
IX. Scalability *[Can the system handle larger or more complex tasks as the user's needs grow?]*		
34	The system was able to handle an increasing amount of data without slowing down or crashing.	1 2 3 4 5
35	The system was able to scale up or down depending on changing needs or requirements.	1 2 3 4 5
36	The system was able to handle a large number of data from different users in one device without sacrificing performance or functionality.	1 2 3 4 5

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37	The system was designed in a way that made it easy to add new features or functionality as needed.	1 2 3 4 5
38	The system was designed in a way that made it easy to integrate with other systems or tools.	1 2 3 4 5
X. Accessibility *[Is the system accessible to users with different abilities? Does it provide support for assistive technologies?]*		
39	The system was designed in a way that made it accessible to athletes with different abilities or disabilities.	1 2 3 4 5
40	The system provided clear and helpful instructions for athletes who may require additional support or accommodation.	1 2 3 4 5
41	The system provided a variety of features or tools to help athletes with different needs or requirements.	1 2 3 4 5
42	The system provided clear and helpful feedback to athletes with different learning styles or preferences.	1 2 3 4 5
43	The system was designed in a way that made it easy for athletes to customize settings or preferences to meet their needs.	1 2 3 4 5
XI. Support *[Is the system accessible to users with different abilities? Does it provide support for assistive technologies?]*		
44	The system provided clear and helpful documentation and resources.	1 2 3 4 5
45	The system provided prompt and helpful support in the event of technical issues or questions.	1 2 3 4 5
46	The system provided a variety of support channels, such as phone, email, or chat.	1 2 3 4 5
47	The system provided helpful tutorials or training resources to help me get started.	1 2 3 4 5
48	The system had a helpful and knowledgeable support team available to assist me.	1 2 3 4 5
XI. Usability *[Is the system easy to learn, use, and navigate? Are the user interfaces intuitive and user-friendly?]*		
49	The wearable device was comfortable to wear during training sessions.	1 2 3 4 5
50	The camera was easy to set up and use during training sessions.	1 2 3 4 5
51	The desktop application was easy to navigate and use.	1 2 3 4 5
52	The system provided clear instructions on how to use the different components.	1 2 3 4 5
53	The system was easy to learn and use, even for someone with limited technology experience.	1 2 3 4 5

StanceUP
YOU CAN DO GREAT AND BE GREAT

PROJECT TITLE: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

USER ACCEPTANCE AND EVALUATION FORM

Instruction: This form serves as an assessment tool evaluating your experience using the StanceUP training system. Rest assured that all your answers will be safe and secure.

The RA 10173, or the Data Privacy Act, protects individuals from unauthorized processing of personal information that is (1) private, not publicly available; and (2) identifiable, where the identity of the individual is apparent either through direct attribution or when put together with other available information. I hereby authorize the researchers to collect and process the data indicated herein.

[ ] I agree and accept the Data Privacy Agreement.

Name (Optional): ______________________________ **Date: June 12,2023**

Current Profession: [ ] Taekwondo Coach [√] Taekwondo Athlete [ ] Other: ____________________

Were you able to see the **whole setup** of the training system? [√] YES [ ] NO

GENERAL INSIGHTS ABOUT THE SETUP OF THE STANCEUP

[Kindly check the corresponding square bracket to your answer]

1. I am satisfied with both the hardware and software of the training system.
[ ] Strongly Agree [√] Agree
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2. I am satisfied with the placement and fitting of the wearable sensors.
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[√] Very Positive [ ] Positive
[ ] Negative [ ] Very Negative

For the Taekwondo Athletes, Coaches and Enthusiasts, would you be interested in investing in this kind of training system?
[√] YES [ ] NO [ ] MAYBE

What do you **like** the most about the training system?

____

____

What do you **dislike** the most about the training system?

____

____

How could the researchers improve the **wearable sensors**?

____

____

How could the researchers improve the **desktop and web applications**?

____

____

LIKERT SCALE PORTION

[Circle your numeric response to each question]

Survey Scale: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

#	Question	
I. Functionality *[Does the system perform the tasks it was designed to do? Does it have all the necessary features and capabilities?]*		
1	The wearable device accurately tracked my movements during training sessions.	1 2 3 4 **5**
2	The Kinect sensor provided clear and complete footage of my training sessions.	1 2 3 4 **5**
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4	The system provided accurate and reliable data for me to analyze my performance.	1 2 **3** 4 5
5	The system helped me identify areas of weakness and suggested exercises to improve them.	1 **2** 3 4 5
II. Effectiveness *[Does the system meet the user's goals and expectations? Does it improve the user's productivity or performance?]*		
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10	The system helped me stay motivated and engaged in my training program.	1 2 3 **4** 5
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12	The system did not experience frequent crashes or technical issues.	1 2 **3** 4 5
13	The system provided accurate and reliable data over an extended period of time.	1 2 3 **4** 5
14	The system was able to recover from technical issues or interruptions quickly.	1 2 **3** 4 5
15	The system was able to function in a variety of different training environments and conditions.	1 2 3 4 **5**
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16	The system provided adequate protection of my personal data and information.	1 2 3 **4** 5
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19	The system had measures in place to prevent unauthorized access to my data.	1 2 3 **4** 5
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47	The system provided helpful tutorials or training resources to help me get started.	1 2 3 4 **5**
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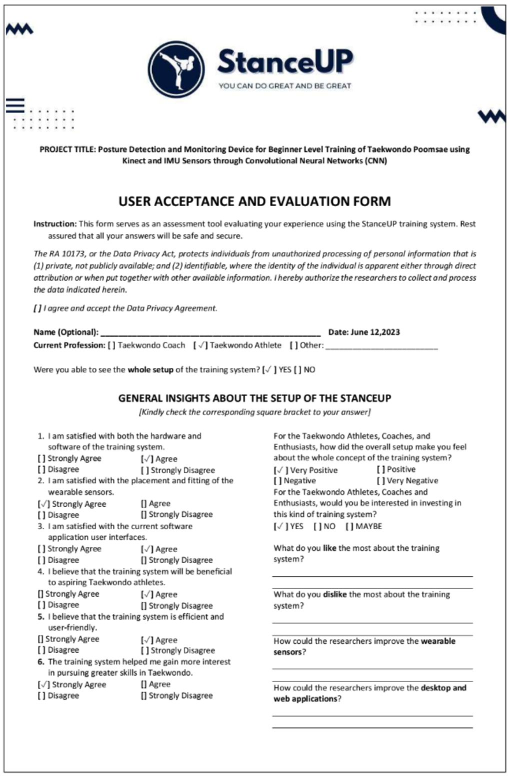
51	The desktop application was easy to navigate and use.	1 2 3 4 **5**
52	The system provided clear instructions on how to use the different components.	1 2 3 4 **5**
53	The system was easy to learn and use, even for someone with limited technology experience.	1 2 3 **4** 5



StanceUP

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[ ] I agree and accept the Data Privacy Agreement.

Name (Optional): ______________________ **Date: June 12,2023**

Current Profession: [ ] Taekwondo Coach [√] Taekwondo Athlete [ ] Other: ____________

Were you able to see the **whole setup** of the training system? [√] YES [ ] NO

GENERAL INSIGHTS ABOUT THE SETUP OF THE STANCEUP

[Kindly check the corresponding square bracket to your answer]

1. I am satisfied with both the hardware and software of the training system.
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[ ] Disagree [ ] Strongly Disagree
2. I am satisfied with the placement and fitting of the wearable sensors.
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[ ] Negative [ ] Very Negative

For the Taekwondo Athletes, Coaches and Enthusiasts, would you be interested in investing in this kind of training system?
[√] YES [ ] NO [ ] MAYBE

What do you **like** the most about the training system?

____

What do you **dislike** the most about the training system?

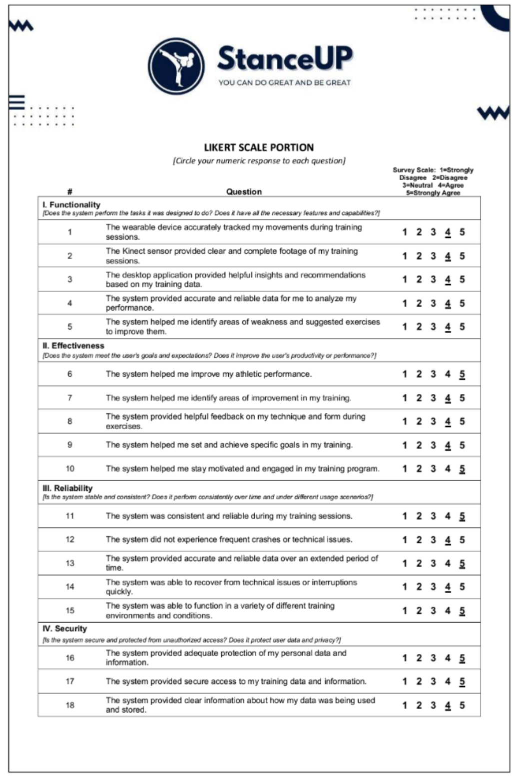
____

How could the researchers improve the **wearable sensors**?

____

How could the researchers improve the **desktop and web applications**?

____



StanceUP

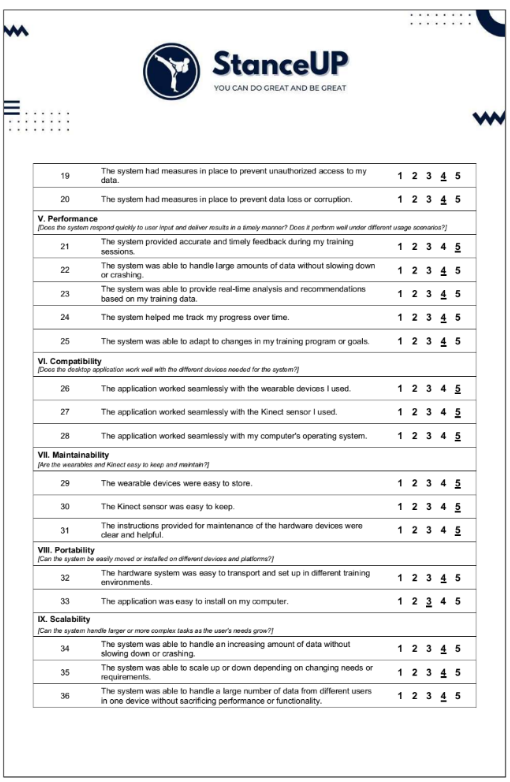
YOU CAN DO GREAT AND BE GREAT

LIKERT SCALE PORTION

[Circle your numeric response to each question]

Survey Scale: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

#	Question					
I. Functionality *[Does the system perform the tasks it was designed to do? Does it have all the necessary features and capabilities?]*						
1	The wearable device accurately tracked my movements during training sessions.	1	2	3	**4**	5
2	The Kinect sensor provided clear and complete footage of my training sessions.	1	2	3	**4**	5
3	The desktop application provided helpful insights and recommendations based on my training data.	1	2	3	**4**	5
4	The system provided accurate and reliable data for me to analyze my performance.	1	2	3	**4**	5
5	The system helped me identify areas of weakness and suggested exercises to improve them.	1	2	3	**4**	5
II. Effectiveness *[Does the system meet the user's goals and expectations? Does it improve the user's productivity or performance?]*						
6	The system helped me improve my athletic performance.	1	2	3	4	**5**
7	The system helped me identify areas of improvement in my training.	1	2	3	**4**	5
8	The system provided helpful feedback on my technique and form during exercises.	1	2	3	**4**	5
9	The system helped me set and achieve specific goals in my training.	1	2	3	**4**	5
10	The system helped me stay motivated and engaged in my training program.	1	2	3	4	**5**
III. Reliability *[Is the system stable and consistent? Does it perform consistently over time and under different usage scenarios?]*						
11	The system was consistent and reliable during my training sessions.	1	2	3	4	**5**
12	The system did not experience frequent crashes or technical issues.	1	2	3	**4**	5
13	The system provided accurate and reliable data over an extended period of time.	1	2	3	4	**5**
14	The system was able to recover from technical issues or interruptions quickly.	1	2	3	**4**	5
15	The system was able to function in a variety of different training environments and conditions.	1	2	3	4	**5**
IV. Security *[Is the system secure and protected from unauthorized access? Does it protect user data and privacy?]*						
16	The system provided adequate protection of my personal data and information.	1	2	3	4	**5**
17	The system provided secure access to my training data and information.	1	2	3	4	**5**
18	The system provided clear information about how my data was being used and stored.	1	2	3	**4**	5



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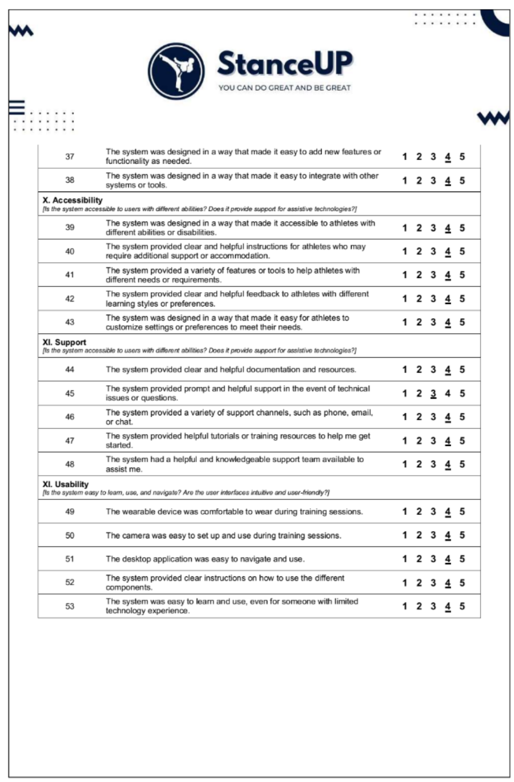
19	The system had measures in place to prevent unauthorized access to my data.	1	2	3	**4**	5
20	The system had measures in place to prevent data loss or corruption.	1	2	3	**4**	5
V. Performance *[Does the system respond quickly to user input and deliver results in a timely manner? Does it perform well under different usage scenarios?]*						
21	The system provided accurate and timely feedback during my training sessions.	1	2	3	4	**5**
22	The system was able to handle large amounts of data without slowing down or crashing.	1	2	3	**4**	5
23	The system was able to provide real-time analysis and recommendations based on my training data.	1	2	3	**4**	5
24	The system helped me track my progress over time.	1	2	3	**4**	5
25	The system was able to adapt to changes in my training program or goals.	1	2	3	**4**	5
VI. Compatibility *[Does the desktop application work well with the different devices needed for the system?]*						
26	The application worked seamlessly with the wearable devices I used.	1	2	3	4	**5**
27	The application worked seamlessly with the Kinect sensor I used.	1	2	3	4	**5**
28	The application worked seamlessly with my computer's operating system.	1	2	3	4	**5**
VII. Maintainability *[Are the wearables and Kinect easy to keep and maintain?]*						
29	The wearable devices were easy to store.	1	2	3	4	**5**
30	The Kinect sensor was easy to keep.	1	2	3	4	**5**
31	The instructions provided for maintenance of the hardware devices were clear and helpful.	1	2	3	4	**5**
VIII. Portability *[Can the system be easily moved or installed on different devices and platforms?]*						
32	The hardware system was easy to transport and set up in different training environments.	1	2	3	**4**	5
33	The application was easy to install on my computer.	1	2	**3**	4	5
IX. Scalability *[Can the system handle larger or more complex tasks as the user's needs grow?]*						
34	The system was able to handle an increasing amount of data without slowing down or crashing.	1	2	3	**4**	5
35	The system was able to scale up or down depending on changing needs or requirements.	1	2	3	**4**	5
36	The system was able to handle a large number of data from different users in one device without sacrificing performance or functionality.	1	2	3	**4**	5



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37	The system was designed in a way that made it easy to add new features or functionality as needed.	1	2	3	**4**	5
38	The system was designed in a way that made it easy to integrate with other systems or tools.	1	2	3	**4**	5
X. Accessibility *[Is the system accessible to users with different abilities? Does it provide support for assistive technologies?]*						
39	The system was designed in a way that made it accessible to athletes with different abilities or disabilities.	1	2	3	**4**	5
40	The system provided clear and helpful instructions for athletes who may require additional support or accommodation.	1	2	3	**4**	5
41	The system provided a variety of features or tools to help athletes with different needs or requirements.	1	2	3	**4**	5
42	The system provided clear and helpful feedback to athletes with different learning styles or preferences.	1	2	3	**4**	5
43	The system was designed in a way that made it easy for athletes to customize settings or preferences to meet their needs.	1	2	3	**4**	5
XI. Support *[Is the system accessible to users with different abilities? Does it provide support for assistive technologies?]*						
44	The system provided clear and helpful documentation and resources.	1	2	3	**4**	5
45	The system provided prompt and helpful support in the event of technical issues or questions.	1	2	**3**	4	5
46	The system provided a variety of support channels, such as phone, email, or chat.	1	2	3	**4**	5
47	The system provided helpful tutorials or training resources to help me get started.	1	2	3	**4**	5
48	The system had a helpful and knowledgeable support team available to assist me.	1	2	3	**4**	5
XI. Usability *[Is the system easy to learn, use, and navigate? Are the user interfaces intuitive and user-friendly?]*						
49	The wearable device was comfortable to wear during training sessions.	1	2	3	**4**	5
50	The camera was easy to set up and use during training sessions.	1	2	3	**4**	5
51	The desktop application was easy to navigate and use.	1	2	3	**4**	5
52	The system provided clear instructions on how to use the different components.	1	2	3	**4**	5
53	The system was easy to learn and use, even for someone with limited technology experience.	1	2	3	**4**	5

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PROJECT TITLE: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

USER ACCEPTANCE AND EVALUATION FORM

Instruction: This form serves as an assessment tool evaluating your experience using the StanceUP training system. Rest assured that all your answers will be safe and secure.

The RA 10173, or the Data Privacy Act, protects individuals from unauthorized processing of personal information that is (1) private, not publicly available; and (2) identifiable, where the identity of the individual is apparent either through direct attribution or when put together with other available information. I hereby authorize the researchers to collect and process the data indicated herein.

[ ] I agree and accept the Data Privacy Agreement.

Name (Optional): ______________________________ **Date: June 12, 2023**

Current Profession: [ ] Taekwondo Coach [✓] Taekwondo Athlete [ ] Other:______________________

Were you able to see the **whole setup** of the training system? [√] YES [ ] NO

GENERAL INSIGHTS ABOUT THE SETUP OF THE STANCEUP

[Kindly check the corresponding square bracket to your answer]

1. I am satisfied with both the hardware and software of the training system.
   [ ] Strongly Agree [√] Agree
   [ ] Disagree [ ] Strongly Disagree
2. I am satisfied with the placement and fitting of the wearable sensors.
   [ ] Strongly Agree [√] Agree
   [ ] Disagree [ ] Strongly Disagree
3. I am satisfied with the current software application user interfaces.
   [ ] Strongly Agree [√] Agree
   [ ] Disagree [ ] Strongly Disagree
4. I believe that the training system will be beneficial to aspiring Taekwondo athletes.
   [√] Strongly Agree [ ] Agree
   [ ] Disagree [ ] Strongly Disagree
5. I believe that the training system is efficient and user-friendly.
   [√] Strongly Agree [ ] Agree
   [ ] Disagree [ ] Strongly Disagree
6. The training system helped me gain more interest in pursuing greater skills in Taekwondo.
   [√] Strongly Agree [ ] Agree
   [ ] Disagree [ ] Strongly Disagree

For the Taekwondo Athletes, Coaches, and Enthusiasts, how did the overall setup make you feel about the whole concept of the training system?
[ ] Very Positive [√] Positive
[ ] Negative [ ] Very Negative

For the Taekwondo Athletes, Coaches and Enthusiasts, would you be interested in investing in this kind of training system?
[√] YES [ ] NO [ ] MAYBE

What do you **like** the most about the training system?

____

What do you **dislike** the most about the training system?

____

How could the researchers improve the **wearable sensors**?

____

How could the researchers improve the **desktop and web applications**?

____

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LIKERT SCALE PORTION

[Circle your numeric response to each question]

#	Question	Survey Scale: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree
I. Functionality *[Does the system perform the tasks it was designed to do? Does it have all the necessary features and capabilities?]*		
1	The wearable device accurately tracked my movements during training sessions.	1 2 3 4 **5**
2	The Kinect sensor provided clear and complete footage of my training sessions.	1 2 3 **4** 5
3	The desktop application provided helpful insights and recommendations based on my training data.	1 **2** 3 4 5
4	The system provided accurate and reliable data for me to analyze my performance.	1 2 **3** 4 5
5	The system helped me identify areas of weakness and suggested exercises to improve them.	1 2 **3** 4 5
II. Effectiveness *[Does the system meet the user's goals and expectations? Does it improve the user's productivity or performance?]*		
6	The system helped me improve my athletic performance.	1 2 3 **4** 5
7	The system helped me identify areas of improvement in my training.	1 2 **3** 4 5
8	The system provided helpful feedback on my technique and form during exercises.	1 2 **3** 4 5
9	The system helped me set and achieve specific goals in my training.	1 **2** 3 4 5
10	The system helped me stay motivated and engaged in my training program.	1 2 3 **4** 5
III. Reliability *[Is the system stable and consistent? Does it perform consistently over time and under different usage scenarios?]*		
11	The system was consistent and reliable during my training sessions.	1 2 3 **4** 5
12	The system did not experience frequent crashes or technical issues.	1 2 **3** 4 5
13	The system provided accurate and reliable data over an extended period of time.	1 2 3 **4** 5
14	The system was able to recover from technical issues or interruptions quickly.	1 2 **3** 4 5
15	The system was able to function in a variety of different training environments and conditions.	1 2 3 4 **5**
IV. Security *[Is the system secure and protected from unauthorized access? Does it protect user data and privacy?]*		
16	The system provided adequate protection of my personal data and information.	1 2 3 **4** 5
17	The system provided secure access to my training data and information.	1 2 3 **4** 5
18	The system provided clear information about how my data was being used and stored.	1 2 3 **4** 5

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19	The system had measures in place to prevent unauthorized access to my data.	1 2 3 **4** 5
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26	The application worked seamlessly with the wearable devices I used.	1 2 3 **4** 5
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51	The desktop application was easy to navigate and use.	1 2 3 **4** 5
52	The system provided clear instructions on how to use the different components.	1 2 3 4 **5**
53	The system was easy to learn and use, even for someone with limited technology experience.	1 2 **3** 4 5

Expert's Evaluation

Project Title: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

StanceUP is a hardware and a software product created to help trainers and athletes in improving the training process and eventually improve the performance of the athletes. With stanceUP, we hope to provide an additional guide to help you improve even on your own. Improvements with lesser possibility of injuries, for a chance of better opportunities. Opportunities far beyond expectation, through innovation after innovation.

Evaluation Form for Experts and Professionals

Direction: Kindly rate our system based on the following criterion.

5 – Excellent 4 – Very Satisfactory 3 – Satisfactory 2 – Fair 1 – Poor

I. General Impact	5	4	3	2	1
1. Novelty of the Project	~~✓~~	✓			
2. Impact to the Sports Industry	✓				
3. Effectiveness	✓				
II. System					
Hardware Devices (Wearable Devices and Camera Sensor)					
1. Design and Aesthetics	✓				
2. Functionality	✓				
3. Safety	✓				
4. Ease of use	✓				
Desktop Application					
5. User-friendliness	✓				
6. Design and Aesthetics	✓				
III. Structural Design					
1. Accuracy	~~✓~~	✓			
2. Reliability	~~✓~~	✓			
3. Maintainability	✓				
4. Portability	✓				

Comments and Suggestions:
→ implementation and technology transfer
→ reliability of performance based on low battery level

Evaluated by:
Julian [illegible] Somera

Project Title: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

StanceUP is a hardware and a software product created to help trainers and athletes in improving the training process and eventually improve the performance of the athletes. With stanceUP, we hope to provide an additional guide to help you improve even on your own. Improvements with lesser possibility of injuries, for a chance of better opportunities. Opportunities far beyond expectation, through innovation after innovation.

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1. Design and Aesthetics	✓				
2. Functionality	✓				
3. Safety	✓				
4. Ease of use	~~✓~~	✓			
Desktop Application					
5. User-friendliness	✓				
6. Design and Aesthetics	✓				
III. Structural Design					
1. Accuracy	✓				
2. Reliability	✓				
3. Maintainability	✓				
4. Portability	✓				

Comments and Suggestions:
—

Evaluated by:
Allan Soria

Project Title: Posture Detection and Monitoring Device for Beginner Level Training of Taekwondo Poomsae using Kinect and IMU Sensors through Convolutional Neural Networks (CNN)

StanceUP is a hardware and a software product created to help trainers and athletes in improving the training process and eventually improve the performance of the athletes. With stanceUP, we hope to provide an additional guide to help you improve even on your own. Improvements with lesser possibility of injuries, for a chance of better opportunities. Opportunities far beyond expectation, through innovation after innovation.

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Direction: Kindly rate our system based on the following criterion.

5 – Excellent 4 – Very Satisfactory 3 – Satisfactory 2 – Fair 1 – Poor

I. General Impact	5	4	3	2	1
1. Novelty of the Project		✓			
2. Impact to the Sports Industry	✓				
3. Effectiveness	✓				
II. System					
Hardware Devices (Wearable Devices and Camera Sensor)					
1. Design and Aesthetics	✓				
2. Functionality	✓				
3. Safety	✓				
4. Ease of use	✓				
Desktop Application					
5. User-friendliness	✓				
6. Design and Aesthetics	✓				
III. Structural Design		✓			
1. Accuracy	~~✓~~	~~✓~~			
2. Reliability		✓			
3. Maintainability		✓			
4. Portability	✓				

Comments and Suggestions:
→ Protection for the device - put an indicator of the device is on connect / amount of [illegible] all are the device / duration of reports, Highest [illegible] & low [illegible]. —

Evaluated by:
[illegible] L [illegible]

Appendix F

User’s Manual

APPENDIX F: USERS' MANUAL

stanceUP

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USER MANUAL

Version 1.0

August 2023

Introduction

This user manual covers the usage and maintenance of the stanceUP wearable devices, Kinect camera, and desktop application.

If you have any questions not available in this user manual, please send an email to the development team at stanceup.ph@gmail.com.

Wearable Devices

The StanceUP system includes five (5) wearable devices to be placed on the user's wrists, area above the ankles, and core. The wearables' purpose is for the collection of the user's angular and orientation data.

Kinect Camera

StanceUP utilizes the Kinect v2 camera, also known as the "Kinect for Xbox One", which was developed by Microsoft. This device is used for obtaining the skeletal data of the user.

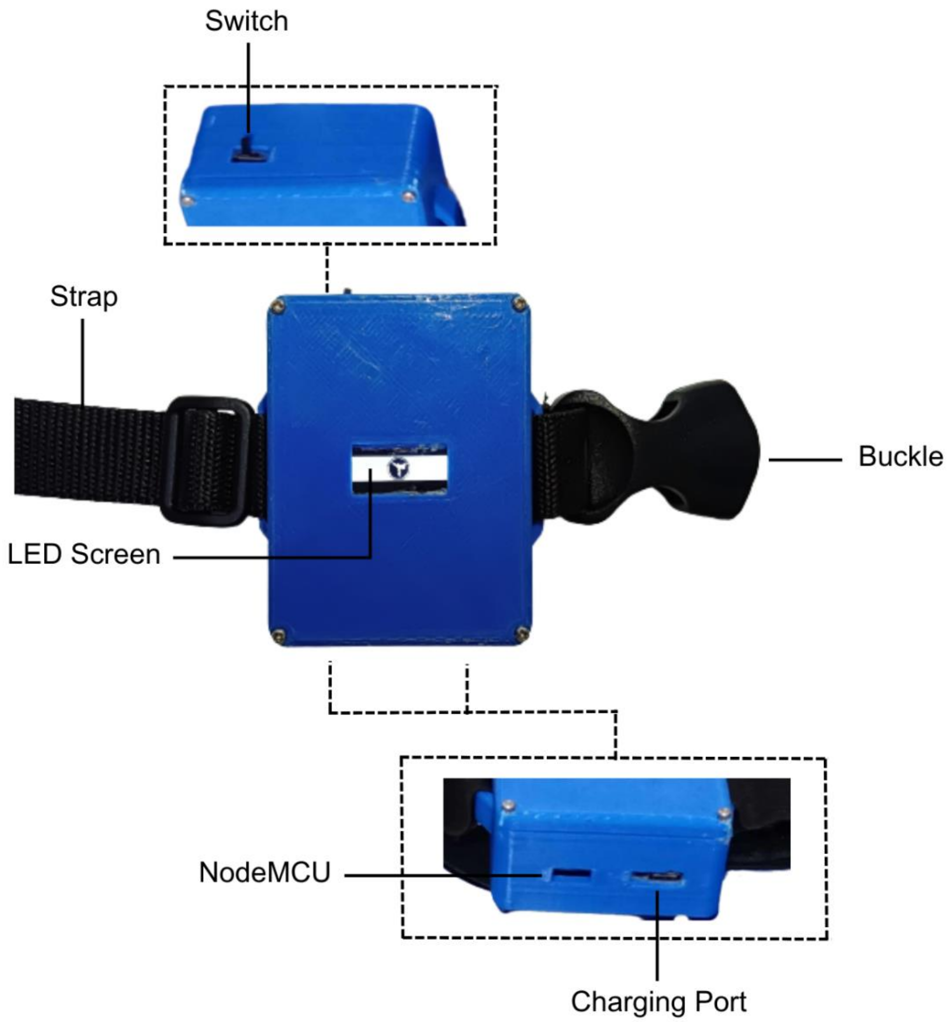
Desktop Application

The StanceUP desktop application serves as the main viewpoint of the user’s training data. It works with the wearable devices and Kinect sensor to collect the parameters needed to analyze the user’s performance. In addition, the application can be used to monitor the user’s progress every training session.

Contents

HARDWARE

Parts



4

Wearable Devices

I. SETTING UP THE SYSTEM

1. Before turning on the wearables, place them on a flat surface.
2. While placed on a flat surface, turn on the wearable devices to start the calibration.
3. Observe the LED screen of the wearables to know the calibration status.

CALIBRATION:

1		3	**CALIBRATION in progress..... Please standby**
2	**Power ON**	4	***Placement indicator stanceUP**

*Right Arm/Left Arm/Core/Right Foot/Left Foot

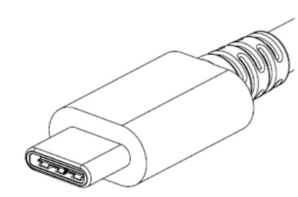
4. Once calibrated, the wearables can be placed on the user's body (wrists, ankles, and core). Make sure to check the indication at the back of each wearable to know where to specifically place each device.

5. The wearables' connectivity to the device can be checked using the desktop application.

NOTE: If the wearable device vibrates, it needs to be calibrated again.

II. CHARGING

- The wearables can be charged using a **Type-C cable**.
- A red indicator will light up if the device is charging, while a blue indicator means that the wearables are already fully charged.
- Charging time is about 45 minutes.



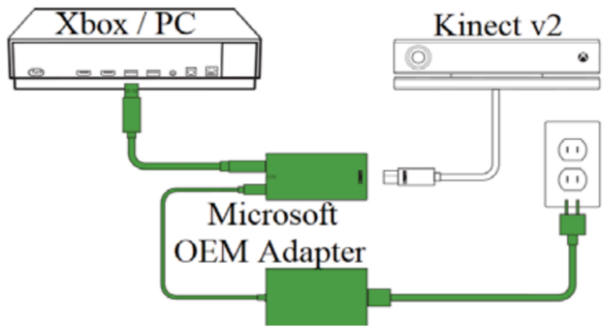
III. TROUBLESHOOTING

- **WiFi Connection**: If the wearable cannot automatically connect to the WiFi, it will create a hotspot that will allow you to manually connect the wearable.
  1. Open the WiFi on your phone or laptop.
  2. Select the WiFi named "TayoTayo_[name of the wearable]" (ex: TayoTayo_LeftFoot).
  3. This will prompt you to which WiFi connection you want to connect with.
  4. Input the credentials.

Kinect Camera

I. SETTING UP THE SYSTEM

1. Connect the Kinect camera to the personal computer as shown.



2. Place the Kinect camera in front of the user using the tripod.

3. Make sure that the Kinect camera can detect the user from head to toe. Its connectivity to the device can be checked in the desktop application.

NOTE: Avoid wearing black clothing and reflective items in training sessions, as these can interfere with the camera and affect its reliability.

II. TROUBLESHOOTING

In case errors are encountered while using the Kinect camera, refer to this link provided by Microsoft: https://learn.microsoft.com/en-us/windows/apps/design/devices/kinect-for-windows

*Kinect Set-up:

Vladimirov, I., Nikolova, D., Terneva, Z. (2019). *Modifying a Kinect v2 sensor to be able to connect to a Windows PC without the use of a Microsoft OEM adapter.* http://rcvt.tu-sofia.bg/ICEST2019_43.pdf

Maintenance

I. Wearable Devices

1. Read the user manual: Be familiarized with the user manual and instructions on how to use the system and wearable devices.
2. Charging of the wearables: The indicator in the wearables will blink if the battery power is low. Use the right cables and port of the wearable devices. Do not overcharge the wearables as it will harm the battery life and performance of the devices.
3. Avoid extreme conditions: Protect the wearables from extreme temperatures, humidity, and direct sunlight. Store the device in a cool dry place. Also, avoid the wearable devices being exposed to water.
4. Cleaning of the wearable: Sanitize the wearable before storing. Clean and change the straps frequently to prevent odors and ensure that it is attached properly.

II. Kinect Camera

1. Positioning of the camera: Place the Kinect camera on the tripod, make sure that it is properly mounted. Hold the camera at the back part gently, making sure that the camera and sensors are not touched.
2. Cleaning the camera: Clean the Kinect camera's lenses and sensors to remove fingerprints and dust that could affect the performance. Wipe the lenses using a soft, lint-free cloth or cleaning solution.
3. Avoid exposure to sunlight: Kinect cameras are sensitive to direct sunlight, this can affect the tracking accuracy of the device, make sure to place the camera away from direct sunlight. Also, store the camera in a cool dry place and ensure that it will not be exposed to water.
4. Cable Management: Avoid bending the cables excessively as it may cause connectivity issues. Take care of the Kinect camera's cables and adaptors since it is expensive and difficult to find a new one.

5. Firmware updates and troubleshooting: Check firmware updates in the website or through the Kinect Studio V2.0 software. Consult the user manual or manufacturer's support resources, or contact customer support for further assistance.

For more support information about the Kinect camera, refer to this link: https://support.xbox.com/en-PH/help/hardware-network/kinect/kinect-sensor-setup-tips

SOFTWARE

Specifications

1. Internet connection is needed when using the StanceUP system.
2. The following should be installed in the personal computer before running the desktop application:
   - XAMPP

     - refer to this link: https://www.apachefriends.org/download.html
   - Kinect for Windows SDK 2.0

     - refer to this link: https://www.microsoft.com/en-us/download/details.aspx?id=44561
3. About 52 GB of storage is expected to be needed **per recording** using the Kinect camera.

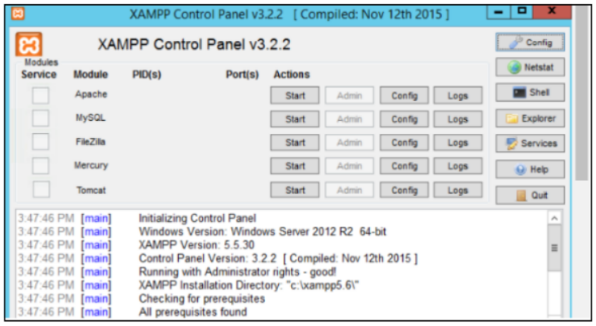
MINIMUM REQUIREMENTS

The PC host hardware requirement is dependent on application/algorithm/sensor frame rate/resolution executed on host PC. Recommended minimum Sensor SDK configuration for Windows is:

- Seventh Gen Intel® CoreTM i3 Processor (Dual Core 2.4 GHz with HD620 GPU or faster)
- 4 GB of RAM
- Dedicated USB3 port
- Graphics driver support for OpenGL 4.4 or DirectX 11.0

USING XAMPP

1. Click “Start” under the Actions column for Apache and MySQL.
2. Leave it running while using the StanceUP desktop application.
3. Click “Stop” under the Actions column after using the stanceUP desktop application.



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Overview

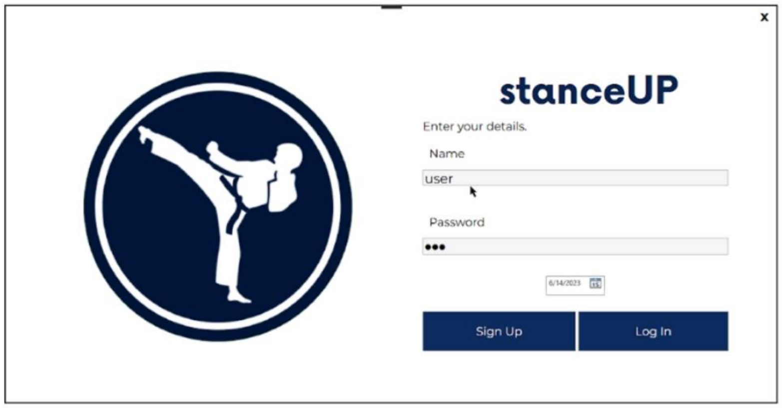
The StanceUP desktop application provides the following features:

- **Sign Up/Log In** - allows the user to create or open their accounts
- **Training Mode** - allows the user to view tutorials of their selected Taegeuk level. This feature also makes it possible to record their performance through the hardware devlices wherein it will be analyzed by the system and give an accuracy percentage accordingly.
    - **Per Movement** - tutorial of the movements one-by-one
    - **All Movements** - continuous sequence of the movements
    - **Start** - for recording
- **Tracking Mode** - enables the user to view their results
- **Account**
    - **Connectivity Verification** - enables the user to check if the wearable devices and the Kinect camera works properly
    - **About** - short description of the application

REMINDERS

- In StanceUP version 1.0, the system can only analyze one movement at a time. With this, the user can only perform one movement per recording.
- Avoid wearing black clothing and reflective items during training sessions as these affect the skeletal tracking of the Kinect camera.

Application



I. CREATE ACCOUNT

1. Fill out the necessary information on the registration form.
2. In the calendar provided, select the date of account creation.
3. Click "Sign Up".
4. A dialog box that says "Account Successfully Created!" will appear on the screen.

NOTE: In case the entered name matches with the name of an existing account, a dialog box that says "Name not available" will appear.

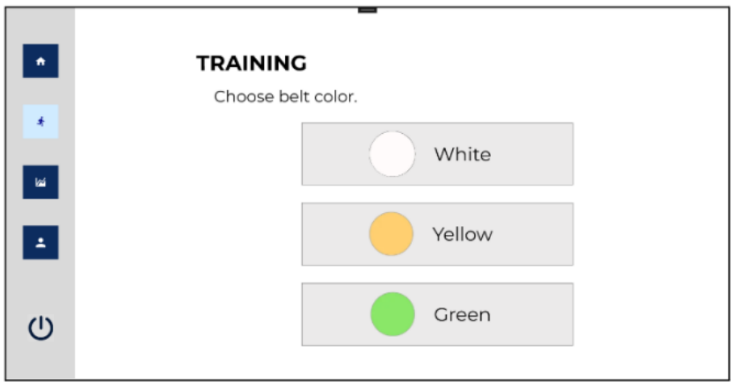
II. LOG IN

1. Enter the name and password.
2. In the calendar provided, select the present date to record the training session.
3. Click "Log In".
4. A dialog box that says "Login Successful" will appear on the screen.

NOTE: In case the password entered is incorrect, a warning that says "Incorrect login information. Please try again." will be displayed.

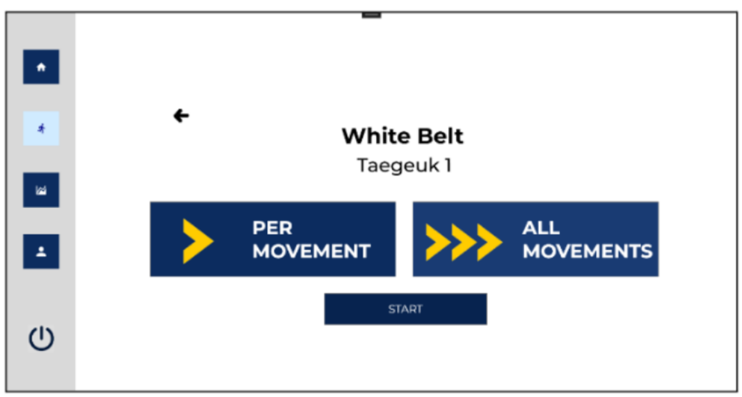
III. TRAINING MODE

1. Select belt color. Each belt color corresponds to a Taegeuk level with different sequences of forms and movements.

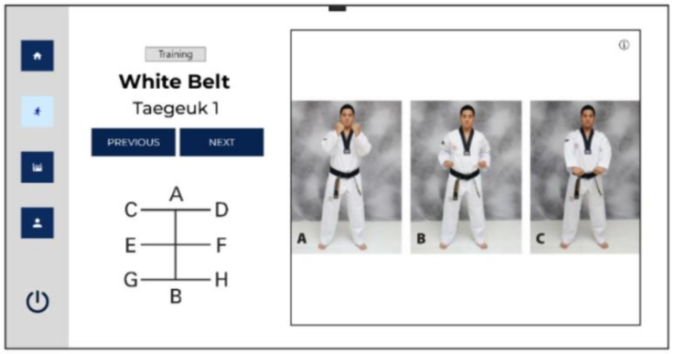


White - Taegeuk 1 | Yellow - Taegeuk 2 | Green - Taegeuk 3 and 4

2. Choose whether you want to practice the Taegeuk level step-by-step (a), continuously (b), or proceed to the recording process (c).



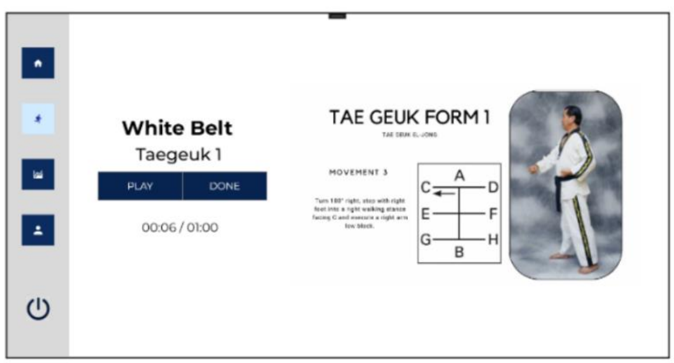
a) **Per Movement**



1. Click “Next” to view the next movement.
2. Click “Previous” to return to the last movement.
3. Click “i” at the upper right corner to view the legend of the letters on the guide pictures provided.

4. Click "Training" to exit the step-by-step tutorial.

b) **All Movements**

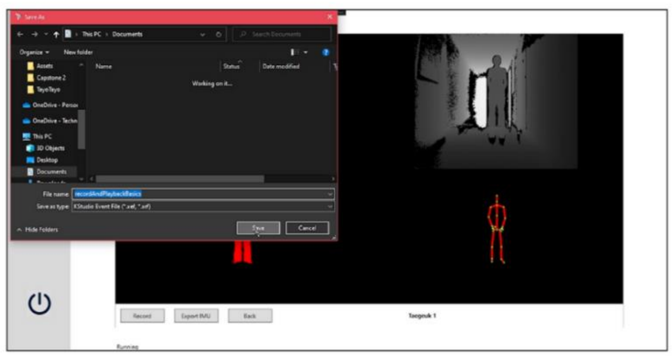


1. Click “Play” to play the slideshow of movements.
2. Click “Done” to exit the tutorial.

c) **Start**

1. Click “Record”. The recording will stop after about five (5) seconds.

2. Save the Kinect recording in your chosen folder.



3. Click “Export IMU”. A dialog box that says "Export completed successfully" will appear.

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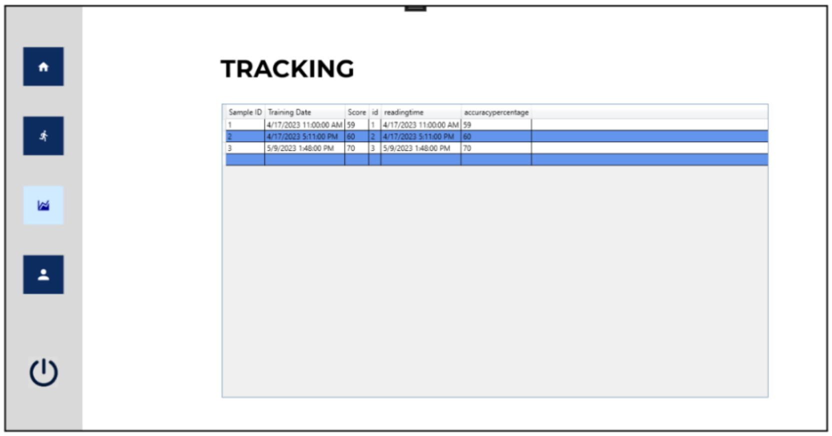
4. Click "Start Processing". You will be asked to submit your Kinect recording and IMU file.

- Look for your Kinect recording (.xef) from your chosen folder.
- Locate your IMU file (.csv) in the Exports folder found in your local drive (ex. C:\Exports).

5. Once submitted, the system will proceed to the processing. This might take a few minutes.

6. A dialog box that says "Processing done. Check the tracking page for your score" will appear.

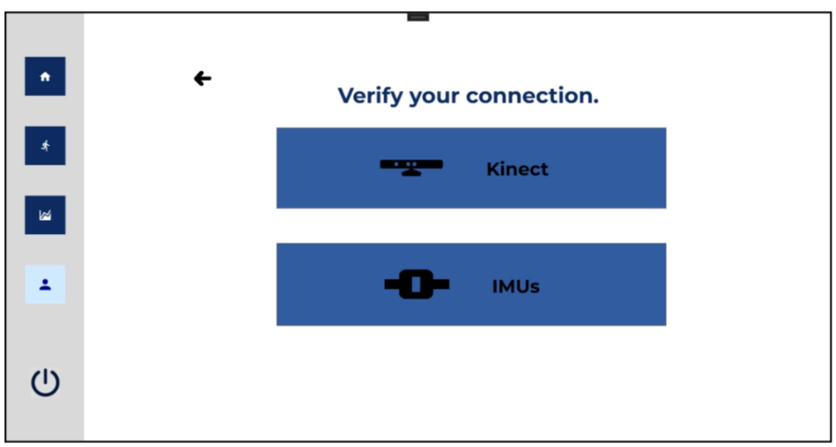
III. TRACKING MODE



- **Sample ID/id** - the number of training attempt
- **Training Date/reading time** - indicates the date and time of the recording/training attempt
- **Score/accuracy percentage** - shows the score of the performance

IV. CONNECTIVITY VERIFICATION

1. Choose whether you want to check the connectivity of the Kinect sensor (a) or IMU/wearable devices (b).



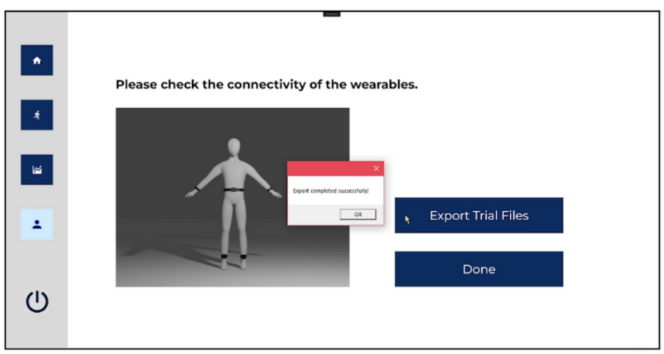
a) **Kinect Sensor**

1. If the screen shows footage from the Kinect sensor, an indicator that says "Running" at the lower left of the screen will appear.
2. Click "Yes".

NOTE: If the screen output is a black screen, an indicator that says, "Kinect not available!" will show instead. Proceed to checking the wire connection of the Kinect to the PC before trying to check the connectivity again.

b) **Wearable Devices**

1. Using the photo provided as a guide, check if the wearables are placed in the right position.

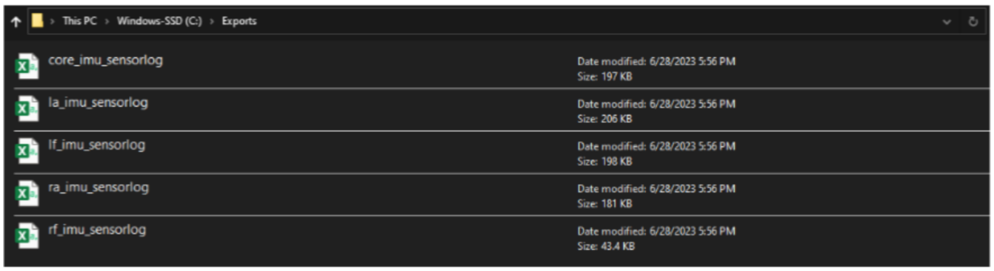


2. To check if the wearable devices are connected to the application, click "Export Trial Files". A dialog box that says "Export completed successfully!" will appear.

3. To make sure that the trial files contain data, go to your local disk (ex. C:\Exports) and locate the Exports folder.

- If there are five .csv files (for each wearable) with corresponding size (i.e., file size ≠ 0) then it just indicate that the wearables are really sending data to the database.

SAMPLE:



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Appendix G

Duplication Manual

APPENDIX G: DUPLICATION MANUAL

stanceUP

you can do great and be great.

DUPLICATION MANUAL

Version 1.0

August 2023

Introduction

This user manual covers the usage and maintenance of the stanceUP wearable devices, Kinect camera, and desktop application.

If you have any questions not available in this user manual, please send an email to the development team at stanceup.ph@gmail.com.

Wearable Devices

The StanceUP system includes five (5) wearable devices to be placed on the user's wrists, area above the ankles, and core. The wearables' purpose is for the collection of the user's angular and orientation data.

Kinect Camera

StanceUP utilizes the Kinect v2 camera, also known as the "Kinect for Xbox One", which was developed by Microsoft. This device is used for obtaining the skeletal data of the user.

Desktop Application

The StanceUP desktop application serves as the main viewpoint of the user's training data. It works with the wearable devices and Kinect sensor to collect the parameters needed to analyze the user's performance. In addition, the application can be used to monitor the user's progress every training session.

Contents

WEARABLES

Components

I. SUMMARY OF COMPONENTS

Quantity	Materials
5	IMU
5	ESP-01s WIFI Module
5	0.91 in OLED LCD
5	5V Voltage Step up Regulator
5	Lithium Ion Battery 3.7V 500 mAh
5	Slide Switch
5	TP 4056 Type C
5	Vibration Module
5	Buckles & straps
5	3D Casing
	Stranded wire (22 AWG)
	Soldering Iron & Lead
	Screws (smallest)

Table 1. Summary of the Materials needed for the Wearables

II. SPECIFICATION OF EACH COMPONENT

1. GY-91 Inertial Measurement Unit

The GY-91 IMU (Inertial Measurement Unit) is a compact and versatile sensor module designed for motion tracking and orientation sensing applications. It combines three essential sensors: a 3-axis accelerometer, a 3-axis gyroscope, and a 3-axis magnetometer, providing accurate and comprehensive motion data.

The GY-91 IMU utilizes advanced MEMS (Microelectromechanical Systems) technology to deliver precise measurements with low power consumption. With its I2C or SPI communication interface, the GY-91 IMU can seamlessly integrate into different microcontroller platforms. It supports voltage levels from 3.3V to 5V, making it compatible with a wide range of electronic systems. Additionally, the module features onboard signal conditioning and filtering for improved accuracy and reliability.
scope, and a 3-axis magnetometer, providing accurate and comprehensive motion data.

2. Vibration Module

The Vibration Motor Module is a compact and versatile device designed to provide haptic feedback in various electronic applications. It consists of a small motor that generates vibrations, allowing users to perceive tactile sensations. The module is typically powered by a voltage source ranging from 3V to 5V, making it compatible with a wide range of electronic systems.

It features a compact form factor, making it easy to integrate into different projects. The vibration motor module is commonly used in applications such as mobile devices, gaming controllers, wearable devices, and notification systems. It provides tactile feedback to enhance user experience, alert users to incoming notifications, and simulate realistic vibrations in gaming scenarios.

3. NodeMCU V3 ESP8266 12E Development Board

The NodeMCU V3 ESP8266 Development Board is a versatile and powerful platform for IoT (Internet of Things) projects. It combines the ESP8266 Wi-Fi module with an integrated microcontroller. The development board is based on the ESP8266 system-on-a-chip (SoC), which features a 32-bit Tensilica microcontroller running at 80MHz.

With built-in Wi-Fi connectivity, the NodeMCU V3 enables seamless communication and data transfer over a wireless network. It supports 802.11 b/g/n protocols, allowing for reliable and secure internet connectivity. The on-board antenna ensures good signal reception and range.

The NodeMCU V3 development board is compatible with the Arduino programming environment, making it easy to develop and upload code using the Arduino IDE. The board features multiple GPIO (General Purpose Input/Output) pins, which can be used for connecting and controlling external devices such as sensors, actuators, and displays. It also includes analog input pins for reading analog signals.

Powering the NodeMCU V3 is simple, as it can be supplied with 5V through a micro-USB port. It can also operate on lower voltages, making it suitable for battery-powered projects.

4. Lithium-Ion Battery

Lithium-ion batteries are a popular and widely used type of rechargeable battery that offers high energy density, long cycle life, and lightweight design. They are commonly used in various portable electronic devices, electric vehicles, and renewable energy systems. Each cell outputs a nominal 3.7V at 500 mAh. Comes terminated with a standard 2-pin JST-PH connector - 2mm spacing between pins. These batteries require special charging.

5. 18650 Type C Lithium-Ion Battery Charger

The 18650 Type C Lithium-Ion Battery Charger is a versatile and efficient charging device specifically designed for charging 18650 lithium-ion batteries. It offers convenient and reliable charging for these popular battery cells used in various electronic devices, flashlights, and power banks.

The charger features a Type C USB port, allowing for easy and reversible connection to power sources. This port supports fast charging and enables high-speed data transfer when connected to compatible devices.

With intelligent charging circuitry, the charger ensures safe and efficient charging of 18650 batteries. It incorporates multiple safety features such as overcharge protection, short circuit protection, and reverse polarity protection, guarding against potential hazards and prolonging battery life.

6. OLED Display Module 12C Interface (128x32 px in 0.91-in screen)

The OLED Display Module with I2C Interface (0.91 inch) is a compact and high-quality display module that offers clear and vibrant visuals. It features a 0.91-inch OLED (Organic Light Emitting Diode) screen with a resolution suitable for displaying text, graphics, and simple animations.

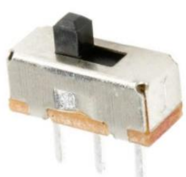
The module is equipped with an I2C (Inter-Integrated Circuit) interface, allowing for easy and convenient communication with microcontrollers and other devices. The I2C interface enables efficient data transfer and requires minimal pins, simplifying the integration process.

7. Pololu 5V Voltage Regulator

The Pololu 5V Voltage Regulator is a reliable and efficient power module designed to provide a stable 5V output voltage for electronic devices and circuits. It is commonly used to power microcontrollers, sensors, motors, and other components that require a consistent and regulated power supply.

The voltage regulator accepts input voltages ranging from 6V to 36V, making it versatile and suitable for a wide range of power sources. It efficiently converts the input voltage to a regulated 5V output with a low ripple and noise level, ensuring clean and reliable power for connected devices.

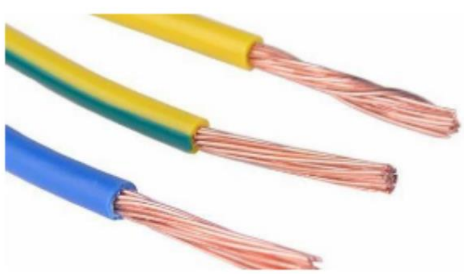
8. SPDT Slide Switch



The SPDT Slide Switch is a compact and versatile switch commonly used in electronic circuits to control the flow of electrical signals. SPDT stands for Single Pole Double Throw, indicating its functionality to connect or disconnect one input to either of two outputs. This slide switch is designed to be easily operated by sliding a lever or actuator to toggle between the different positions. It offers tactile feedback, allowing users to clearly feel the switch position.

OTHER MATERIALS USED:

1. Stranded Wires



Stranded wires are a type of electrical wire that consists of multiple smaller strands of conductive material twisted or braided together. This construction provides several advantages over solid core wires, including flexibility, durability, and resistance to breaking or cracking.

2. Buckles and Straps

Buckles and straps are commonly used together as a fastening and securing system in various applications. Buckles are hardware devices that are designed to join and lock two ends of a strap, while straps are flexible bands made of materials such as nylon, polyester, or leather. Buckles come in a variety of designs and styles, each suited for specific applications and requirements.

3. Stainless Steel Screws

Stainless steel screws are commonly used in wearable devices due to their excellent strength, durability, and corrosion resistance. They provide a reliable fastening solution for securing components and assemblies in wearable technology.

4. Soldering Iron and Lead

A soldering iron is a handheld tool used for soldering electronic components and wires. It consists of a heated metal tip that melts solder, allowing it to flow and create a secure electrical connection. When it comes to soldering, the term "lead" refers to the solder alloy that contains lead as one of its primary components.

Connection Guides

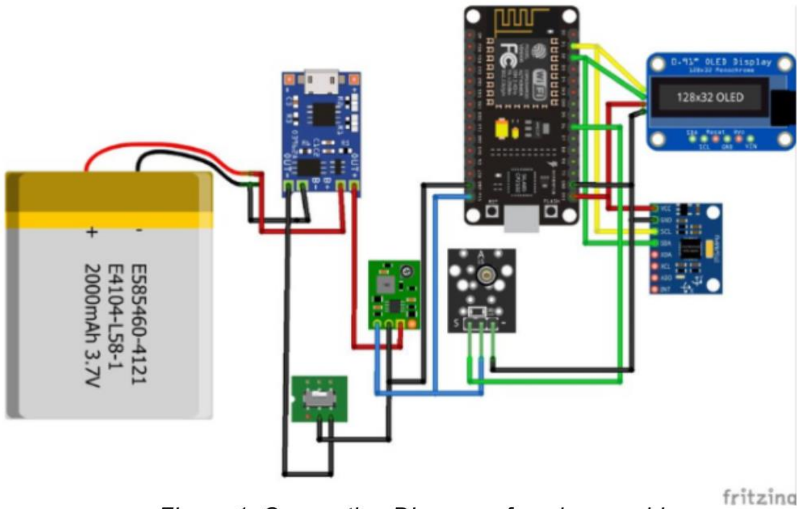


Figure 1. Connection Diagram of each wearables

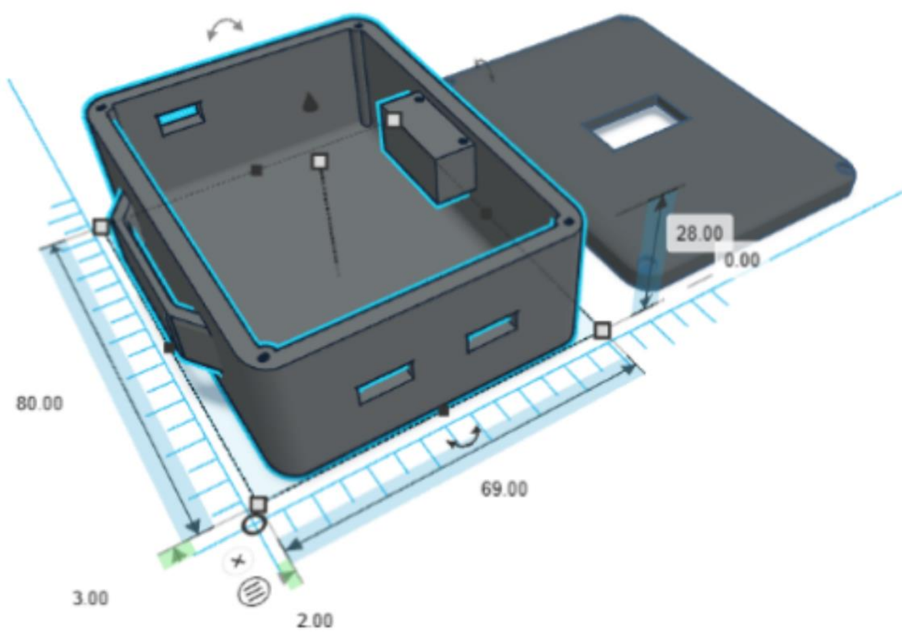
Component 1	Pin	Component 2	Pin
NODEMCU	D1	OLED & IMU	SCL
NODEMCU	D2	OLED & IMU	SDA
NODEMCU	D6	Vibration Module	IN
NODEMCU	GND	Vibration Module	GND
		OLED & IMU	
		POLOLU 5V Reg	
NODEMCU	3V	OLED	VCC
		IMU	3V3
NODEMCU	VIN	POLOLU 5V Reg	VOUT
		Vibration Module	VCC
POLOLU 5V Reg	GND	Slide Switch	Middle Pin
POLOLU 5V Reg	VIN	TP 4056	OUT +
TP 4056	OUT -	Slide Switch	Rightmost Pin
TP 4056	B -	Battery	Negative
TP 4056	B +	Battery	Positive

Table 2. Summary of Pins Connection

3D Printed Casing

I. DESIGN PROTOTYPING

The figures below shows the dimensions that the case requires. The prototyping were done in TinkerCAD. The .stl files for this can be accessed on the SD Card that comes along with this manual.



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II. 3D PRINTING THE DESIGN

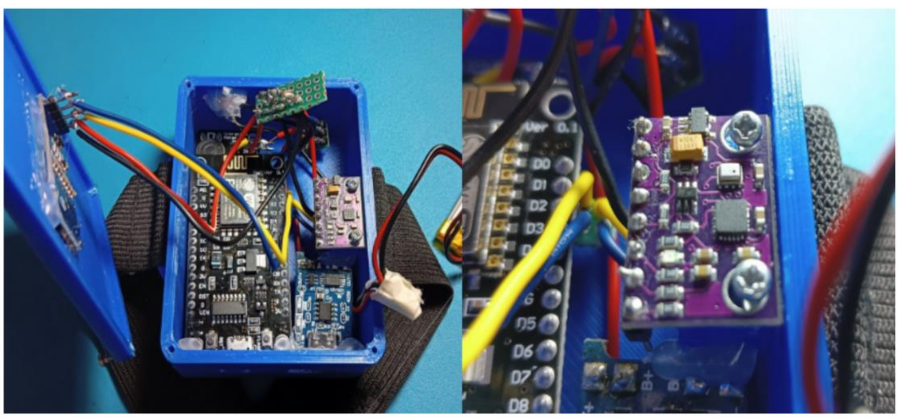
PETG 3D Filament

PETG (Polyethylene Terephthalate Glycol-Modified) is a popular type of 3D printing filament known for its durability, flexibility, and ease of use. It is a thermoplastic material that combines the strength of ABS filament with the ease of printing of PLA filament. It has excellent layer adhesion, resulting in strong and durable printed parts. It also exhibits good impact resistance, making it less prone to cracking or breaking compared to other filaments.

PETG filament is known for its high transparency and clarity, similar to glass. PETG is also resistant to moisture and chemicals, providing stability and durability in various environments.

Construction and Testing

1. Connect all the devices based on the schematic design created. Do this first through a breadboard to test if the codes and connections are correct.
2. Upload the codes to the Node MCU of the respective wearables (check Appendix G)
3. Once tested, connect all the hardware components by soldering it based on the connections in the schematic design. Note that the wiring should be enough for the components to be placed into the wearable casing.



Important Notes:

- The Pololu and the TP-4056 are very sensitive, handle and solder them with care.
- The main chip of Wi-Fi module gradually heat up with time, always take note of this fact while handling the module.

DATASET GATHERING

Components Needed

1. Kinect V2

The Microsoft Kinect for Xbox One is a cutting-edge motion sensing device that revolutionizes the way users interact with their applications.

Equipped with a high-resolution depth sensor, the Kinect can accurately track the movement of multiple people in 3D space. It captures depth information, skeletal tracking, and facial recognition, allowing for precise and responsive motion tracking. The device also includes a 1080p RGB camera for capturing high-quality video and images.

The Kinect for Xbox One features a wide-angle lens that provides a broad field of view. Its microphone array enables voice commands and voice chat, enhancing the overall user experience and enabling seamless interaction with the console.

2. Kinect Tripod

A Kinect on a tripod setup involves mounting the Kinect sensor on a tripod for stable and adjustable positioning. The Kinect sensor is a motion-sensing device developed by Microsoft that can capture depth and RGB images, enabling gesture recognition and 3D scanning capabilities.

3. Wearable System

The wearable system is placed on the left and right arm, left and right foot, and core of the user, allowing it to track the user’s position and facing. The data gathered are the acceleration/velocity and angle changes of nodes of the human body.

4. Pocket WiFi

The pocket wifi is used as the gateway of the wearable system to transmit the data from the wearables to the software.

Recording Process

I. KINECT DATASET GATHERING

1. Setup the Kinect V2 with the tripod and plug the necessary wirings.
2. On your computer, install Kinect Studio V2.0. Connect the Kinect to your computer and make sure that in the monitor tab, it is connected.
3. Once connected, you can see on the screen the view that is seen by the Kinect and also the skeletal diagram.
4. Before recording, make sure that the following streams are selected and visible:
    a. Nui Body Frame
    b. Nui Body Index
    c. Nui Calibration Data
    d. Nui Depth
    e. Nui IR
    f. Nui Long Exposure IR
    g. Nui Opaque Data
    h. Nui Sensor Telemetry

II. IMU DATASET GATHERING

1. Make sure that you have a database setup in MySQL. This MySQL database should have five tables inside, and each table should have nine rows as set up in the image below.

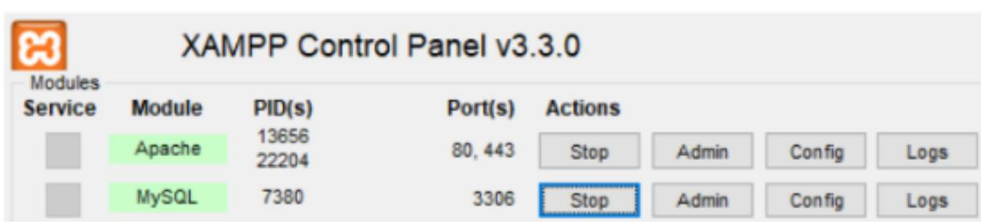
	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	id	int(10)		UNSIGNED	No	None		AUTO_INCREMENT
☐	2	reading_time	timestamp			No	current_timestamp()		ON UPDATE CURRENT_TIMESTAMP()
☐	3	gxValue	decimal(5,2)			Yes	NULL		
☐	4	gyValue	decimal(5,2)			Yes	NULL		
☐	5	gzValue	decimal(5,2)			Yes	NULL		
☐	6	AngleXValue	decimal(5,2)			Yes	NULL		
☐	7	AngleYValue	decimal(5,2)			Yes	NULL		
☐	8	AngleZValue	decimal(5,2)			Yes	NULL		
☐	9	orientation	varchar(30)	utf8mb4_general_ci		No	None		

2. Once the database has been set up, ensure that the wearable devices have been properly coded to connect through a Wireless Local Area Network and send data to the MySQL database.

3. Prepare the wearables by placing them on a flat surface before turning them on. After turning them on, wait for the devices to calibrate. You will hear or feel a vibration, indicating that the devices have completed the calibration process. If the devices only display the logo on their OLED display, it means that they haven't yet established a connection with the database and WiFi. Refer to the user's manual for instructions on troubleshooting the wearables' connectivity to available access points.

4. Once the devices have been calibrated, you can place the wearables on specific body parts: wrists, areas above the ankles, and the core/torso. The devices have built-in indicators that show which wearable should be placed on a particular body part.

5.For data gathering, ensure that the computer has the XAMPP control panel installed. Open the program and click "Start" under the "Actions" column for both Apache and MySQL. Keep them running until the user has finished performing for the dataset. This will ensure that the connectivity between the wearables and MySQL remains open.



6. After the data gathering, open localhost/phpmyadmin/ on your web browser. Here, you can view the MySQL dashboard and check the sensor data from the data gathering process.

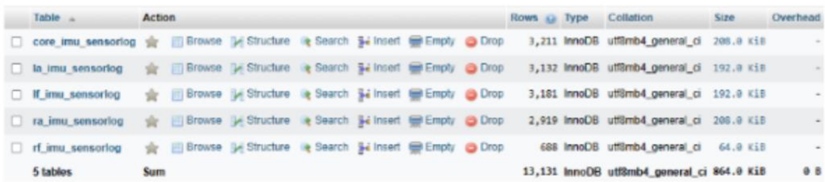


Table	Action	Rows	Type	Collation	Size	Overhead
core_imu_sensorlog	Browse Structure Search Insert Empty Drop	3,211	InnoDB	utf8mb4_general_ci	208.0 KiB	-
la_imu_sensorlog	Browse Structure Search Insert Empty Drop	3,132	InnoDB	utf8mb4_general_ci	192.0 KiB	-
lf_imu_sensorlog	Browse Structure Search Insert Empty Drop	3,181	InnoDB	utf8mb4_general_ci	192.0 KiB	-
ra_imu_sensorlog	Browse Structure Search Insert Empty Drop	2,919	InnoDB	utf8mb4_general_ci	208.0 KiB	-
rf_imu_sensorlog	Browse Structure Search Insert Empty Drop	688	InnoDB	utf8mb4_general_ci	64.0 KiB	-
5 tables	Sum	13,131	InnoDB	utf8mb4_general_ci	864.0 KiB	0 B

7. The data gathered and stored inside the MySQL database can be exported as sql, csv, xslx, and json files.

Appendix H

Compilation of System Codes

APPENDIX H: COMPILATION OF ALL THE CODES IN THE STUDY

CODES FOR THE HARDWARE SYSTEM

Code Snippets for the Wearables

```
// StanceUP Codes for the Wearables
// by TayoTayo est. 2022
// EK Bernas, SN Cabrera, MK Cuya, JP David, GN Garufil
// Note: Usage of this sketch without permission from the program owners is prohibited.
// Changes must be made for each sketch to meet the requirements per wearable.

// Include needed libraries
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClient.h>
#include <MPU9250_WE.h>
#include <Wire.h>
#include <SPI.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
//#include <WiFiManager.h>
//WiFiManager wifiManager;

// Define variables
#define MPU9250_ADDR 0x68
const int VIBRATION = 12; //D6
MPU9250_WE myMPU9250 = MPU9250_WE(MPU9250_ADDR);
const char* ssid     = "*****";                  //change to the available wifi ssid
const char* password = "*****";                  //change to the available wifi password
String sendval, sendval2, sendval3, sendval4, sendval5, sendval6, sendval7;

// Use this API Key value for more security. Changes in this value must be synced with the
backend php file.
```

```
// String apiKeyValue = "aBcDT5Ab3j7F9";

Adafruit_SSD1306 display(128, 32, &Wire, -1);

// 'stanceUP-removebg-preview', 128x32px
const unsigned char myBitmap [] PROGMEM = {
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf8, 0x0f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xc3, 0xe1, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x3c, 0x1c, 0x7f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xfe, 0x60, 0x03, 0x3f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xfd, 0x80, 0x00, 0x9f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xfb, 0x00, 0x00, 0x4f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf2, 0x80, 0x00, 0x27, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf4, 0xe0, 0x00, 0x17, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xe8, 0x79, 0x81, 0xdb, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xc8, 0x3d, 0x81, 0xcb, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x1f, 0xff, 0xc1, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x07, 0xbf, 0x85, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x03, 0xbf, 0x85, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x01, 0xff, 0x85, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0xff, 0x85, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0xe3, 0x05, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0xc0, 0x05, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0xe0, 0x05, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0x60, 0x05, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xd0, 0x00, 0x60, 0x05, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xc8, 0x00, 0xe0, 0x09, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xe8, 0x00, 0xe0, 0x0b, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xec, 0x00, 0xe0, 0x13, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf4, 0x00, 0xe0, 0x37, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
```

```
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf2, 0x00, 0x20, 0x6f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf9, 0x00, 0x20, 0xcf, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xfc, 0xc0, 0x01, 0xbf, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x30, 0x06, 0x7f, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x8f, 0xf8, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xe0, 0x03, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
  0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff
};

void setup() {
  Serial.begin(115200);

  display.begin(SSD1306_SWITCHCAPVCC, 0x3C);
  display.clearDisplay();
  display.drawBitmap(0, 0, myBitmap, 128, 32, WHITE);
  display.display();
  delay(2000);
  display.clearDisplay();

  Wire.begin();
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
       delay(500);
       display.print(".");
       //wifiManager.autoConnect("TayoTayo_RightFoot", "stanceup"); //change based on the
wearable device
    }

  testdrawstyles();
  testscrolltext();
  testdrawstylesA();
```

```
  pinMode(VIBRATION, OUTPUT);
  digitalWrite(12, HIGH);     //define used pin in the NodeMCU
  delay(1000);
  digitalWrite(12, LOW);

  Serial.println("");
  Serial.print("Connected to WiFi network with IP Address: ");
  Serial.println(WiFi.localIP());

  Serial.println("Calibrating...");
  delay(1000);
  myMPU9250.autoOffsets();
  Serial.println("Done!");

  /*  This is a more accurate method for calibration. You have to determine the minimum and
maximum
   *  raw acceleration values of the axes determined in the range +/- 2 g.
   *  You call the function as follows: setAccOffsets(xMin,xMax,yMin,yMax,zMin,zMax);
   *  Use either autoOffset or setAccOffsets, not both.
   */
  //myMPU9250.setAccOffsets(-14240.0, 18220.0, -17280.0, 15590.0, -20930.0, 12080.0);

  /*  Sample rate divider divides the output rate of the gyroscope and accelerometer.
   *  Sample rate = Internal sample rate / (1 + divider)
   *  It can only be applied if the corresponding DLPF is enabled and 0<DLPF<7!
   *  Divider is a number 0...255
   */
  //myMPU9250.setSampleRateDivider(5);

  myMPU9250.setAccRange(MPU9250_ACC_RANGE_2G);
```

```
  myMPU9250.enableAccDLPF(true);
  myMPU9250.setAccDLPF(MPU9250_DLPF_6);
}

void loop() {
  xyzFloat gValue = myMPU9250.getGValues();
  xyzFloat angle = myMPU9250.getAngles();
  String orientation = myMPU9250.getOrientationAsString();

/* For g-values the corrected raws are used */
  Serial.print("g-x      = ");
  Serial.print(gValue.x);
  Serial.print("  |  g-y      = ");
  Serial.print(gValue.y);
  Serial.print("  |  g-z      = ");
  Serial.println(gValue.z);

  /* Angles are also based on the corrected raws. Angles are simply calculated by angle =
arcsin(g Value) */
  Serial.print("Angle x  = ");
  Serial.print(angle.x);
  Serial.print("  |  Angle y  = ");
  Serial.print(angle.y);
  Serial.print("  |  Angle z  = ");
  Serial.println(angle.z);

  Serial.print("Orientation of the module: ");
  Serial.println(myMPU9250.getOrientationAsString());
  delay(100);

  //Check WiFi connection status
```

```
  if(WiFi.status()== WL_CONNECTED){
    WiFiClient client;
    HTTPClient http;

  sendval = String(gValue.x);
  sendval2 = String(gValue.y);
  sendval3 = String(gValue.z);
  sendval4 = String(angle.x);
  sendval5 = String(angle.y);
  sendval6 = String(angle.z);
  sendval7 = String(orientation);

    // Your Domain name with URL path or IP address with path
   // URL Path must be changed depending on the wearable device
    http.begin(client, "http://192.168.8.100/stanceUP_rf_db/post_stanceup_rf.php");

    // Specify content-type header
    http.addHeader("Content-Type", "application/x-www-form-urlencoded");  //Specify
content-type header

    // Prepare your HTTP POST request data
    String postData = "&sendval=" + sendval + ", &sendval2=" + sendval2
                    + ", &sendval3=" + sendval3 + ", &sendval4=" + sendval4
                    + ", &sendval5=" + sendval5 + ", &sendval6=" + sendval6
                    + ", &sendval7=" + sendval7;
    Serial.print("Values are: ");
    Serial.println(postData);

    int httpCode = http.POST(postData);   // Send POST request to php file and store server
response code in variable named httpCode
    // if connection eatablished then do this
```

```
  if (httpCode == 200) { Serial.println("Values uploaded successfully.");
Serial.println(httpCode);
    String webpage = http.getString();  // Get html webpage output and store it in a string
    Serial.println(webpage + "\n");}
    else {
    // if failed to connect then return and restart
    Serial.println(httpCode);
    Serial.println("Failed to upload values. \n");
    http.end();
    return;
  }
}
}

void testdrawstyles(void) {
  display.clearDisplay();

  display.setTextSize(2.5);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(25,10);
  display.println(F("PowerON"));

  display.display();
  delay(2000);
}

void testscrolltext(void) {
  display.clearDisplay();

  display.setTextSize(1.9);
  display.setTextColor(SSD1306_WHITE);
```

```
  display.setCursor(5,0);
  display.println(F("CALIBRATION"));
  display.setTextSize(1);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(5,10);
  display.println(F("in progress..."));
  display.setTextSize(1);
  display.setCursor(5,24);
  display.println(F("Please standby"));
  display.display();
  delay(100);

  display.startscrollleft(0x00, 0x0F);
  delay(8000);
  display.stopscroll();
  delay(5000);
}

void testdrawstylesA(void) {
  display.clearDisplay();

  display.setTextSize(1);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(15,0);
  display.println(F("Right Foot")); // change the name depending on the wearable device

  display.setTextSize(2.9);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(15,12);
  display.println(F("stanceUP"));
```

```
  display.display();
  delay(1000);
}
```

Code Snippets for the Database Creation

For the Connectivity:

```
<?php
// host = localhost because database hosted on the same server where PHP files are hosted
//everything prefixed with $ is a PHP variable
    $host = "localhost";
    $dbname = "stanceup_db";            // Database name
    $username = "*****";                // Database username; Encrypted to protect the stored
dataset
    $password = "*****";          // Database password; Encrypted to protect the stored dataset
    // Establish connection to MySQL database, using the inbuilt MySQLi library.
    $conn = new mysqli($host, $username, $password, $dbname);
    // Check if connection established successfully
    if ($conn->connect_error) {
        die("Connection failed: " . $conn->connect_error);
    } else {
        echo "Connected successfully. ";
    }
 //$_POST is a PHP Superglobal that assists us to collect/access the data, that arrives in the
form of a post request made to this script.
  // If values sent by NodeMCU are not empty then insert into MySQL database table
  if(!empty($_POST['sendval']) && !empty($_POST['sendval2']) &&
!empty($_POST['sendval3']) && !empty($_POST['sendval4']) &&
!empty($_POST['sendval5']) && !empty($_POST['sendval6']) &&
!empty($_POST['sendval7']) ){
        // "sendval" and "sendval2" are query parameters accessed from the HTTP POST
Request made by the NodeMCU.
```

```
            $gxValue = $_POST['sendval'];
            $gyValue = $_POST['sendval2'];
            $gzValue = $_POST['sendval3'];
            $AngleXValue = $_POST['sendval4'];
            $AngleYValue = $_POST['sendval5'];
            $AngleZValue = $_POST['sendval6'];
            $orientation = $_POST['sendval7'];
        // Update your tablename here
        // A SQL query to insert data into table -> INSERT INTO table_name (col1, col2, ...,
colN) VALUES (' " .$col1. " ', '".col2."', ..., ' ".colN." ')
                $sql = "INSERT INTO core_imu_sensorlog (gxValue, gyValue, gzValue,
AngleXValue, AngleYValue, AngleZValue, orientation) VALUES
('".$gxValue."','".$gyValue."','".$gzValue."','".$AngleXValue."','".$AngleYValue."','".$Angle
ZValue."','".$orientation."')";
                    if ($conn->query($sql) === TRUE) {
                        // If the query returns true, it means it ran successfully
                        echo "Values inserted in MySQL database table.";
                    } else {
                        echo "Error: " . $sql . "<br>" . $conn->error;
                    }
            }
    // Close MySQL connection
    $conn->close();
?>
```

For the SQL Setup:

```
// Change table name depending on the wearable device being coded
CREATE TABLE RA_imu_sensorlog (
    id INT(10) UNSIGNED AUTO_INCREMENT PRIMARY KEY,
    reading_time TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE
CURRENT_TIMESTAMP
```

```
    gxValue DECIMAL(5,2),
    gyValue DECIMAL(5,2),
    gzValue DECIMAL(5,2),
    AngleXValue DECIMAL(5,2),
    AngleYValue DECIMAL(5,2),
    AngleZValue DECIMAL(5,2),
    orientation VARCHAR(30) not null
);
```

CODES FOR THE SOFTWARE SYSTEM

Code Snippets for the Desktop Application's Main Window

```
<Window x:Class="stanceup_new.MainWindow"
        xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
        xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
        xmlns:d="http://schemas.microsoft.com/expression/blend/2008"
        xmlns:mc="http://schemas.openxmlformats.org/markup-compatibility/2006"
        xmlns:local="clr-namespace:stanceup_new"
        xmlns:NavButton="clr-namespace:stanceup_new"
        mc:Ignorable="d"
        Title="MainWindow"
        Icon="Assets/taekwondo.ico"
        x:Name="stanceUP"
        Height="700"
        Width="1350"
        WindowStyle="None"
        AllowsTransparency="True"
        ResizeMode="NoResize"
        WindowStartupLocation="CenterScreen"
        Background="Transparent">
    <Grid>
```

```
    <Grid Background="white">
        <Grid.ColumnDefinitions>
            <ColumnDefinition Width="130"/>
            <ColumnDefinition Width="407*"/>
        </Grid.ColumnDefinitions>
        <Image Source="/Assets/stanceUP.png"
               Grid.Column="1"
               Height="300"
               VerticalAlignment="Top"
               Margin="0,105,0,0"></Image>
        <TextBlock Text="stanceUP"
                   Foreground="#011638"
                   Grid.Column="1"
                   FontFamily="{StaticResource Now}"
                   FontSize="90"
                   HorizontalAlignment="Center"
                   Margin="0,395,0,0">
        </TextBlock>
        <TextBlock Text="you can do great and be great."
                   Foreground="Black"
                   Grid.Column="1"
                   FontFamily="{StaticResource Montserrat}"
                   FontSize="40"
                   HorizontalAlignment="Center"
                   Margin="0,500,0,0">
        </TextBlock>
    </Grid>
    <ListBox SelectionMode="Single" SelectionChanged="sidebar_SelectionChanged"
Background="#D9D9D9" Grid.Column="0" x:Name="sidebar" Margin="0,0,1220,0"
BorderThickness="0">
```

```
            <local:NavButton NavLink="/Pages/Home.xaml" Margin="3,70,0,0" Padding="3"
Icon="M10,20V14H14V20H19V12H22L12,3L2,12H5V20H10Z" Height="63"
Width="66"></local:NavButton>
            <local:NavButton NavLink="/Pages/Training.xaml" Margin="3,50,0,0" Padding="3"
Icon="M13.5,5.5C14.59,5.5 15.5,4.58 15.5,3.5C15.5,2.38 14.59,1.5 13.5,1.5C12.39,1.5
11.5,2.38 11.5,3.5C11.5,4.58 12.39,5.5
13.5,5.5M9.89,19.38L10.89,15L13,17V23H15V15.5L12.89,13.5L13.5,10.5C14.79,12
16.79,13 19,13V11C17.09,11 15.5,10 14.69,8.58L13.69,7C13.29,6.38 12.69,6 12,6C11.69,6
11.5,6.08
11.19,6.08L6,8.28V13H8V9.58L9.79,8.88L8.19,17L3.29,16L2.89,18L9.89,19.38Z"
Height="63" Width="66"></local:NavButton>
            <local:NavButton NavLink="/Pages/Tracking.xaml" Margin="3,50,0,0" Padding="3"
Icon="M17.45,15.18L22,7.31V19L22,21H2V3H4V15.54L9.5,6L16,9.78L20.24,2.45L21.97,
3.45L16.74,12.5L10.23,8.75L4.31,19H6.57L10.96,11.44L17.45,15.18Z" Height="63"
Width="66"></local:NavButton>
            <local:NavButton NavLink="/Pages/Account.xaml" Margin="3,50,0,100"
Padding="3" Icon="M12,4A4,4 0 0,1 16,8A4,4 0 0,1 12,12A4,4 0 0,1 8,8A4,4 0 0,1
12,4M12,14C16.42,14 20,15.79 20,18V20H4V18C4,15.79 7.58,14 12,14Z" Height="63"
Width="66"></local:NavButton>
            <Button BorderThickness="0" Click="btnclick_close" Width="50"
Margin="35,0,0,0">
                <Image Source="/Assets/Shutdown.png"
                       Height="50" Width="50" Margin="0,0,0,0"></Image>
            </Button>
        </ListBox>
        <Frame Grid.Column="1"
               x:Name="navframe"
               NavigationUIVisibility="Hidden" Margin="130,0,0,0"/>
    </Grid>
</Window>
```

```
using System.Windows;
using System.Windows.Controls;

namespace stanceup_new
{
    /// <summary>
    /// Interaction logic for MainWindow.xaml
    /// </summary>
    public partial class MainWindow : Window
    {
        public MainWindow()
        {
            InitializeComponent();
        }
        private void sidebar_SelectionChanged(object sender, SelectionChangedEventArgs e)
        {
            var selected = sidebar.SelectedItem as NavButton;
            navframe.Navigate(selected.NavLink);
        }
        private void btnclick_close(object sender, RoutedEventArgs e)
        {
            Application.Current.Shutdown();
        }
```

Appendix I

Documentation

APPENDIX I: DOCUMENTATION

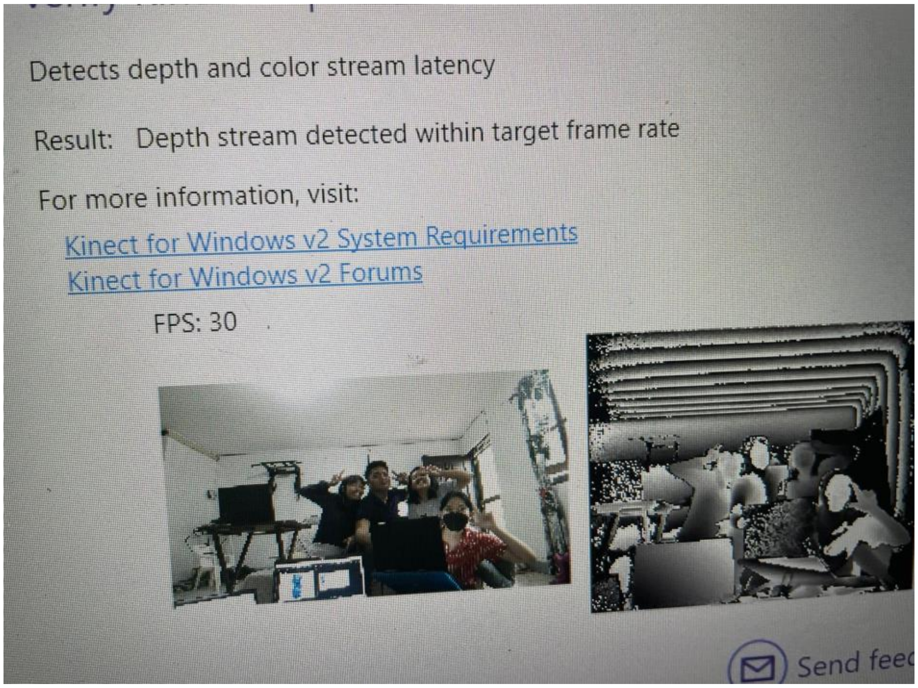


Figure I.1. Initial Testing of the Kinect

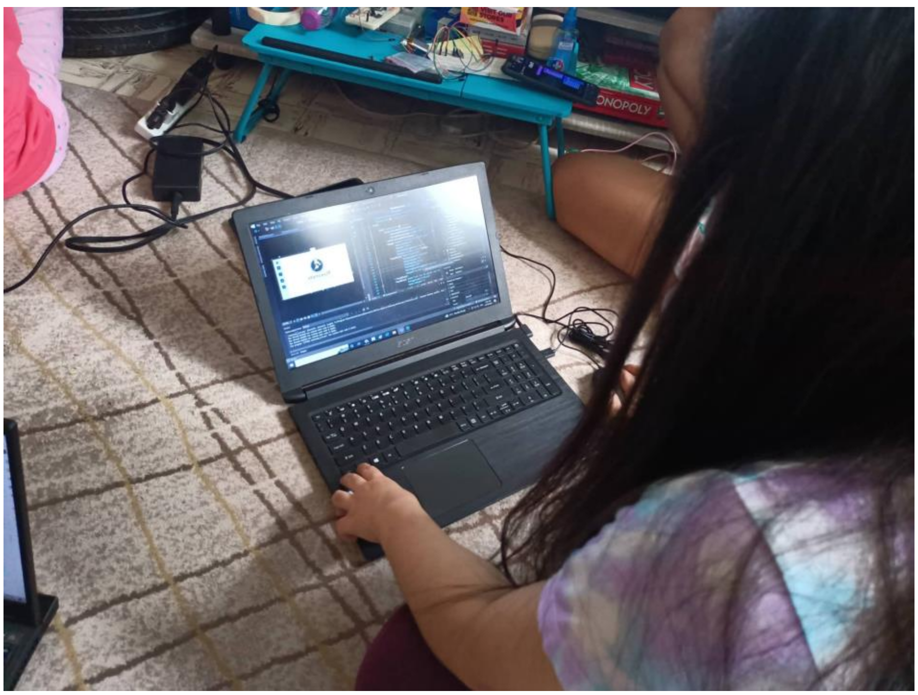


Figure I.2. Front-End Coding

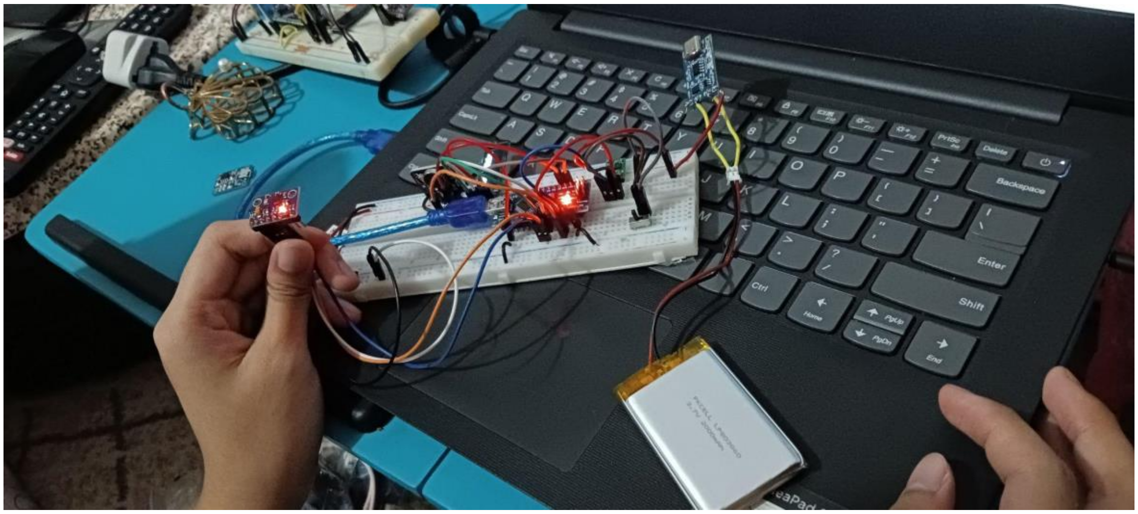


Figure I.3. Breadboarding and Testing Connections

3D Printing of the Casing

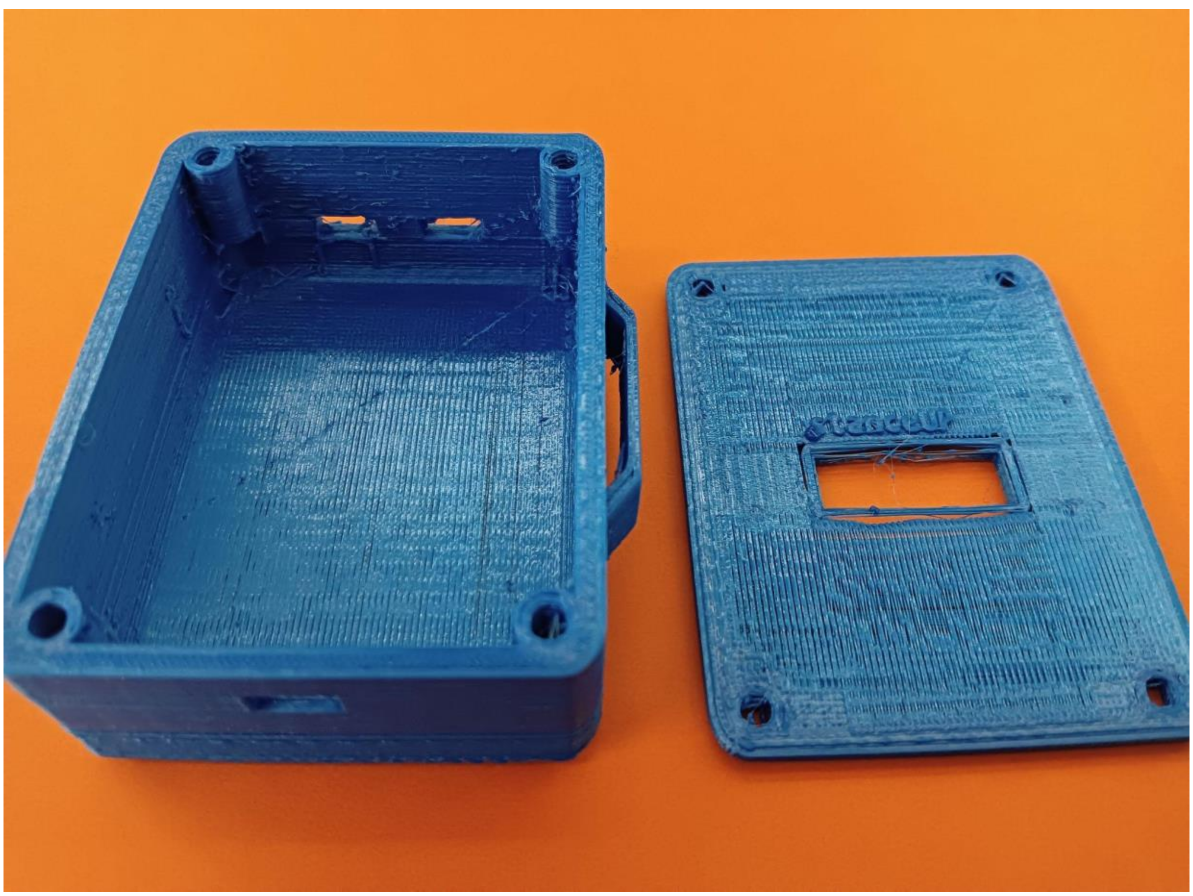


Figure I.4. Version 1 of the Case Design

Figure I.5. 3D Printing at COE with assistance from Engr. John Peter Ramos

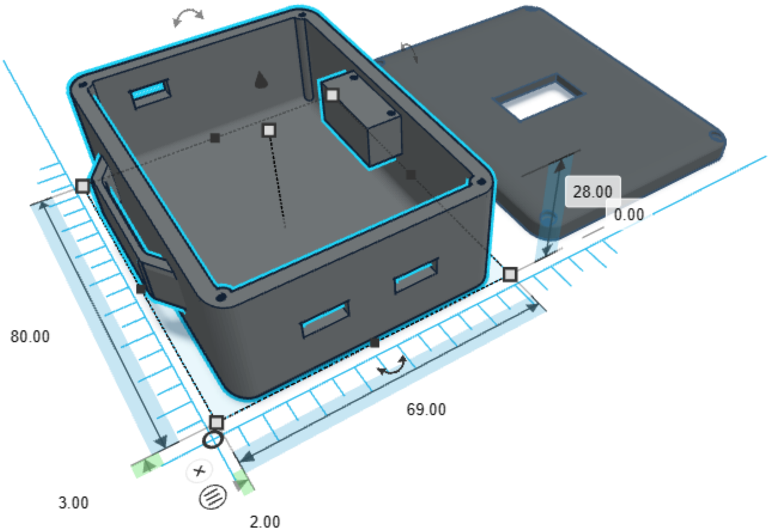


Figure I.6. Version 2 (Final) of the 3D Printed Casing

System Assembly

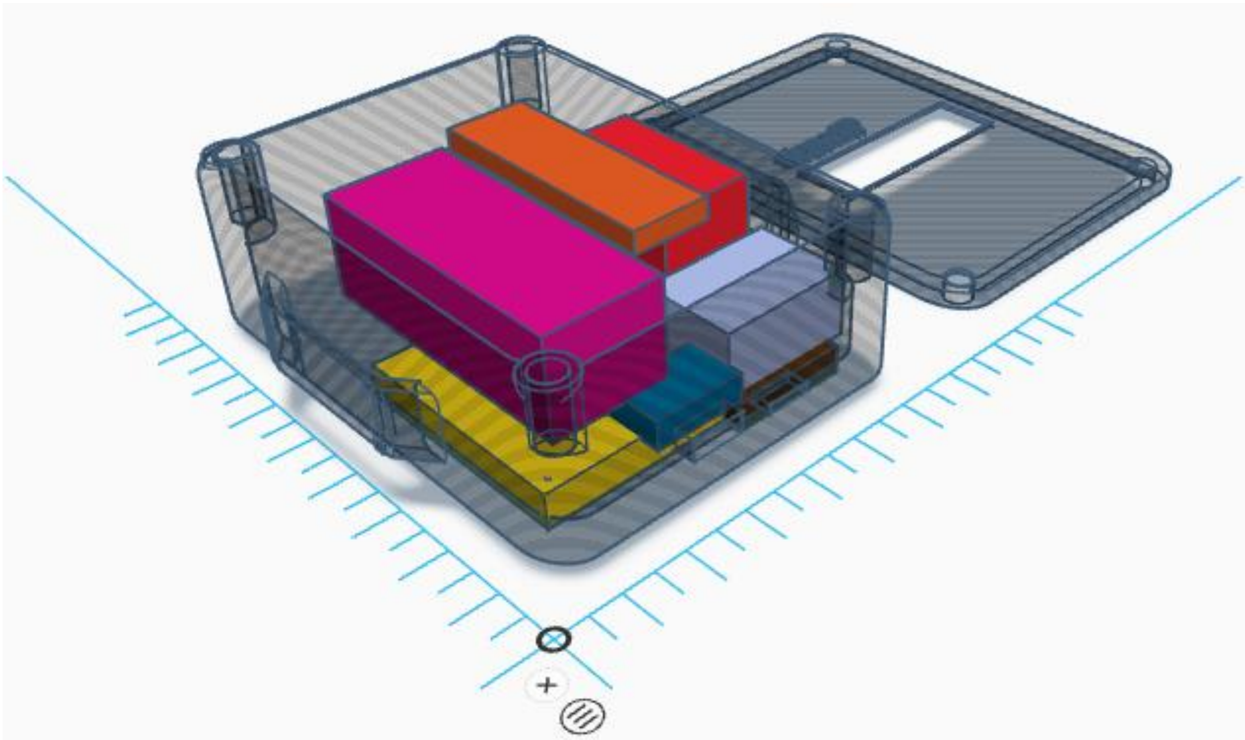


Figure I.7. Initial Placements of the Components in the Casing

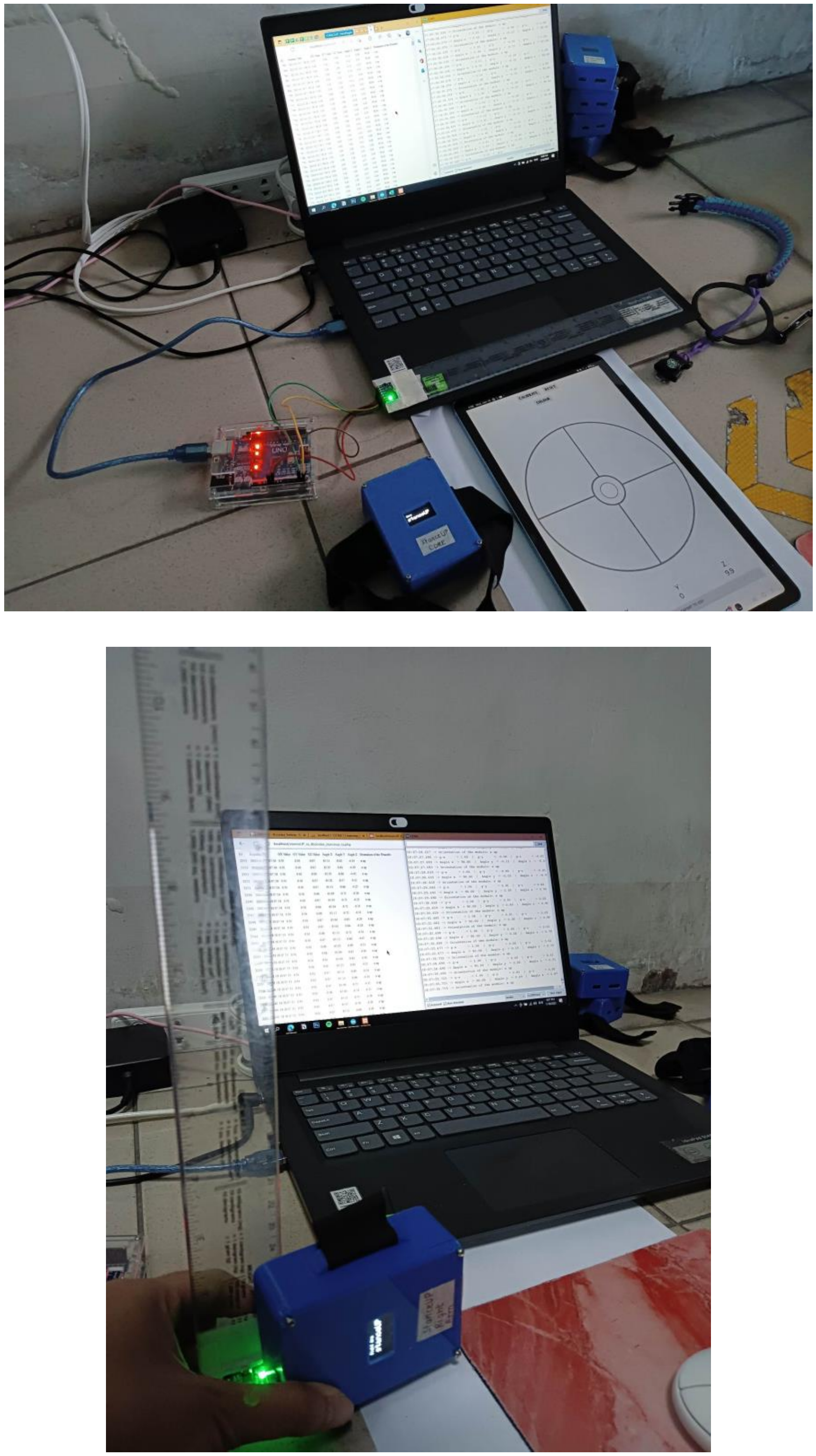


Figure I.8. Accuracy Testing and Calibration of the Wearables

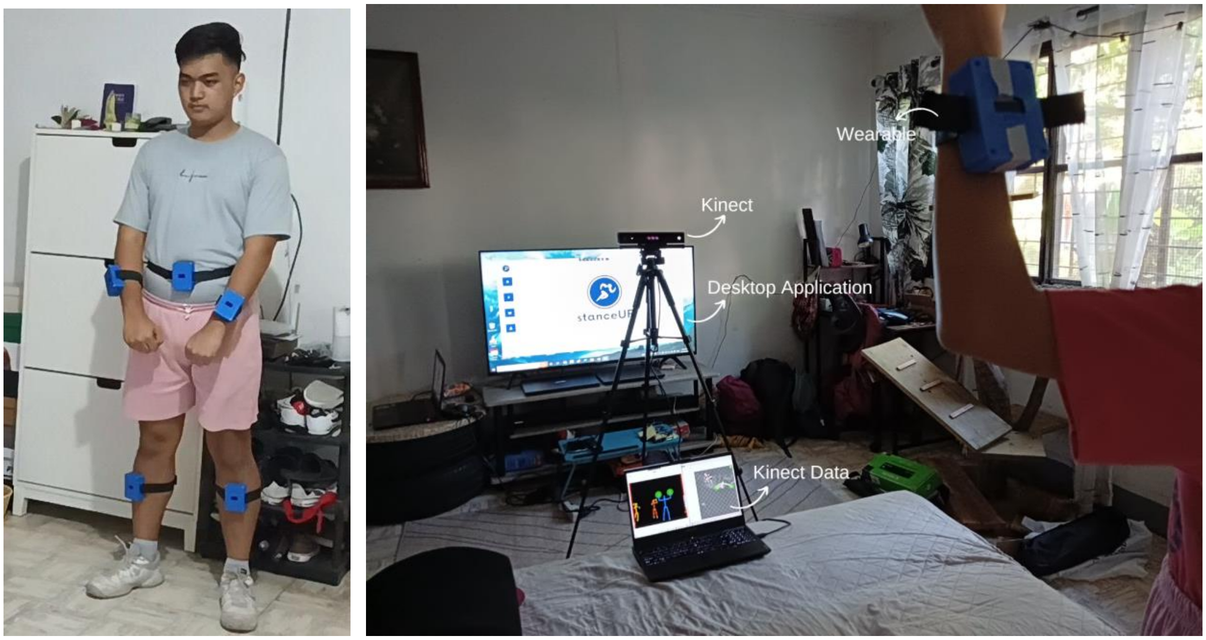


Figure I.9. Initial Rundown of the System

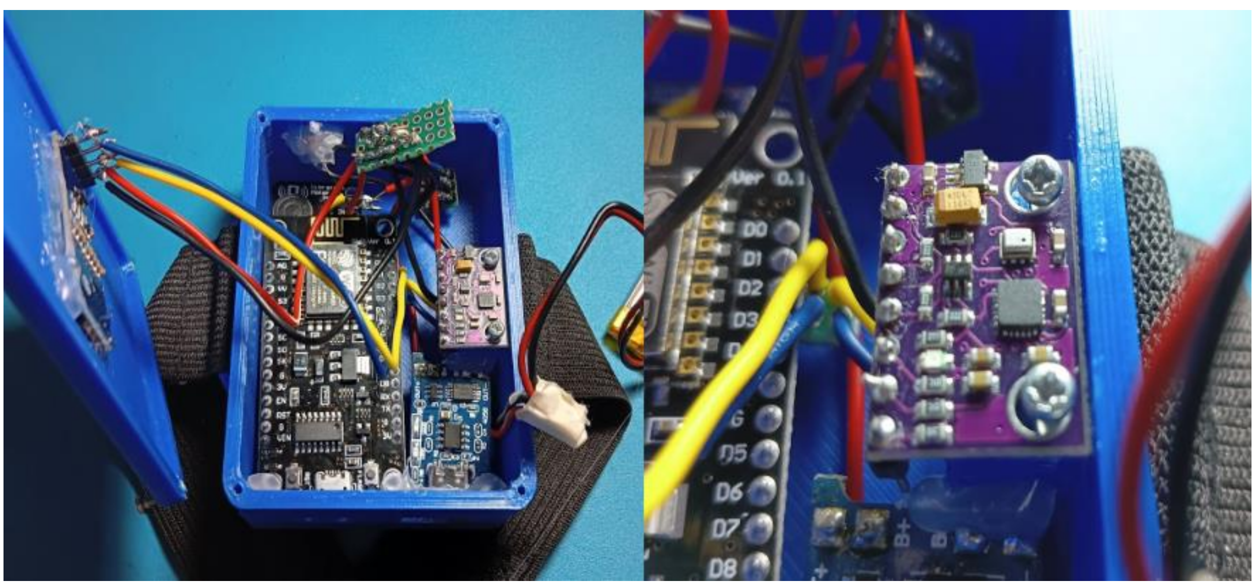


Figure I.10. Final Placement of the Components inside the Case

Figure I.11. Wearable System (Final Look)

INTERVIEW WITH EXPERTS

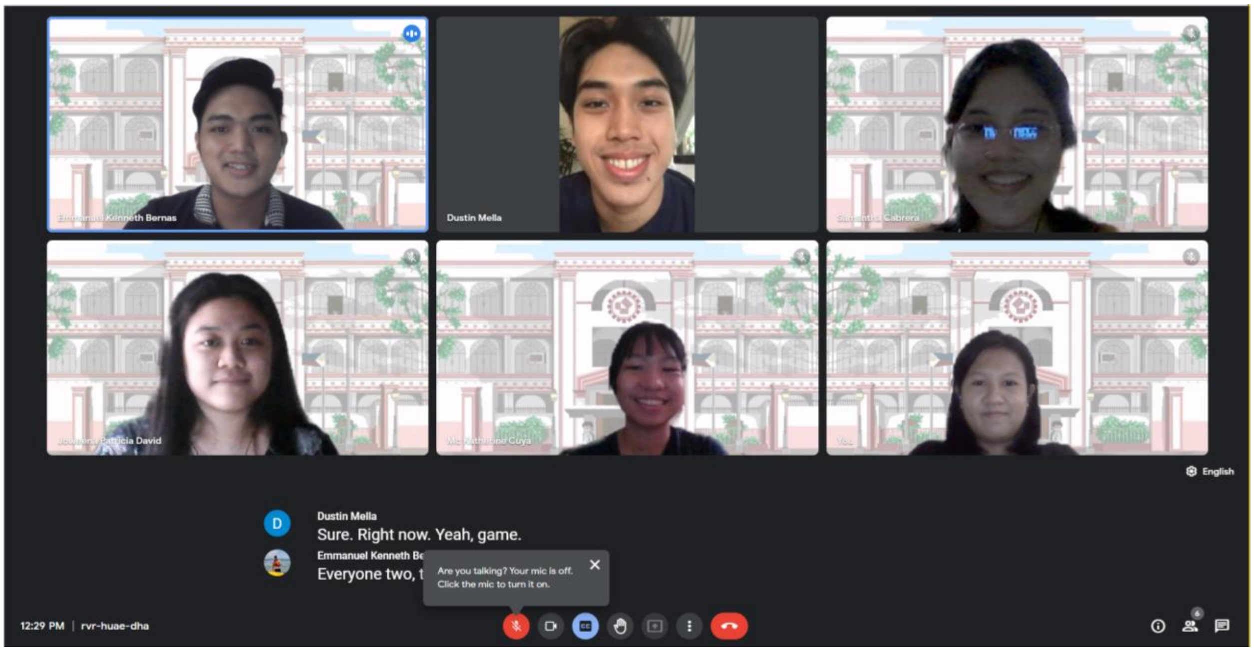


Figure I.13. Interview with Coach Dustin Mella, one of the coaches of Poomsae National from Philippine Taekwondo Association (PTA)

Figure I.14. Interview with Coach Balajadia of TUP Manila Taekwondo Team and Familiarization with the testing environment and process

Figure I.15. Expert's Evaluation with Prof. Julius Sareno, Director of UITC

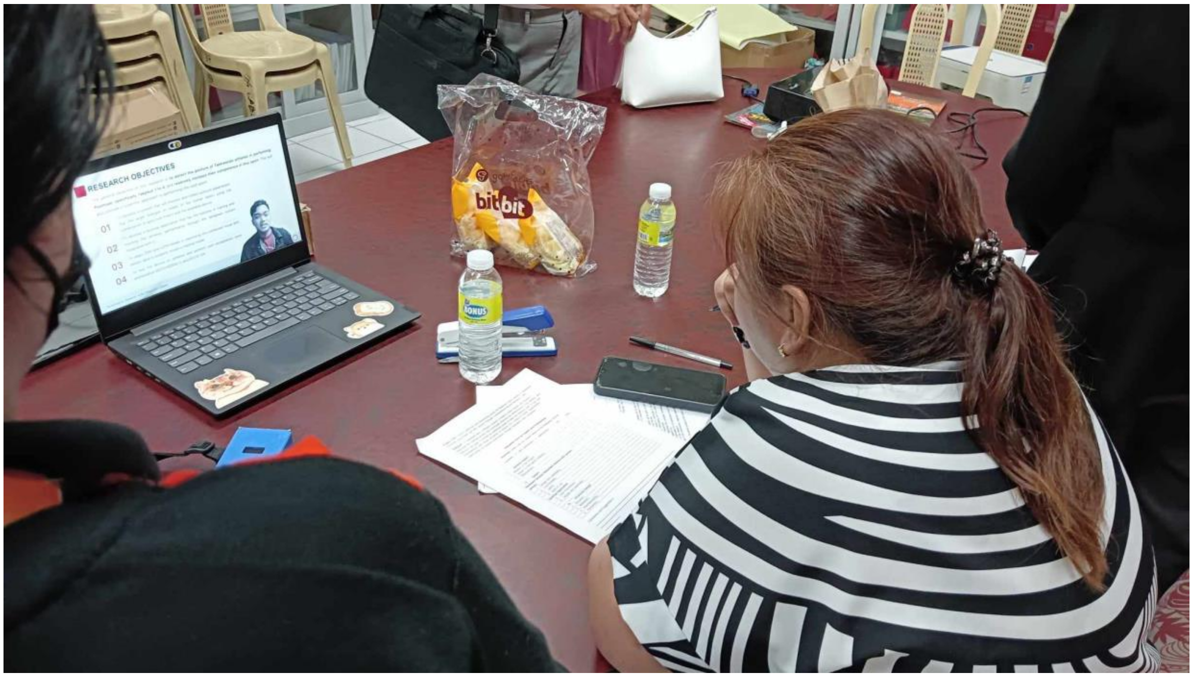


Figure I.16. Experts' Evaluation with Prof. Dolores Montesines, Head of the Computer Science Department of TUP - College of Science

DATA GATHERING AND DEPLOYMENT

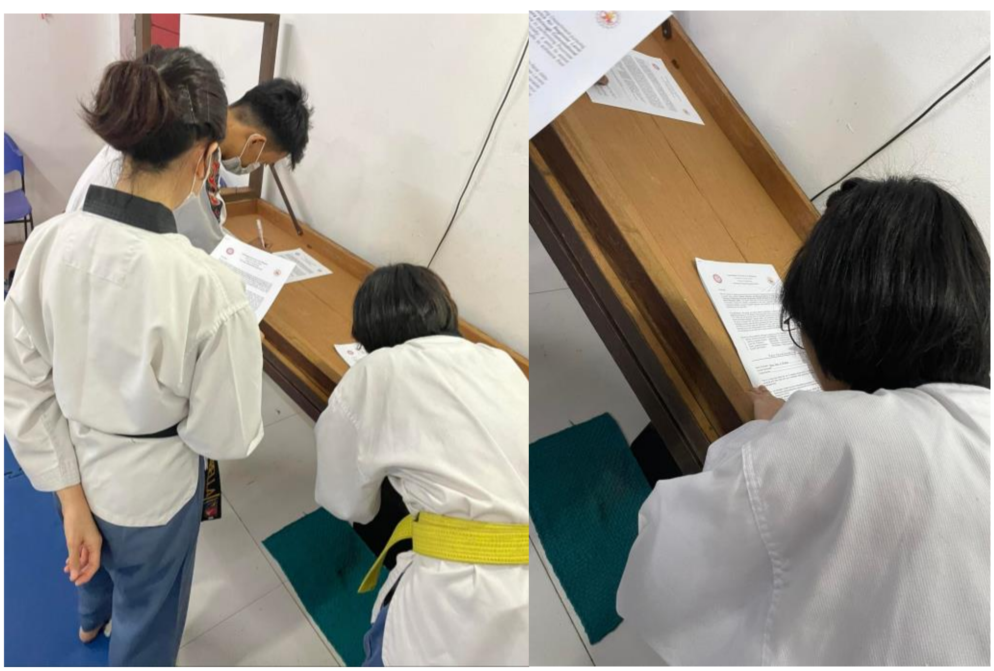


Figure I.17. The signing of the Waiver Form

Figure I.18. First batch of Data Gathering Run

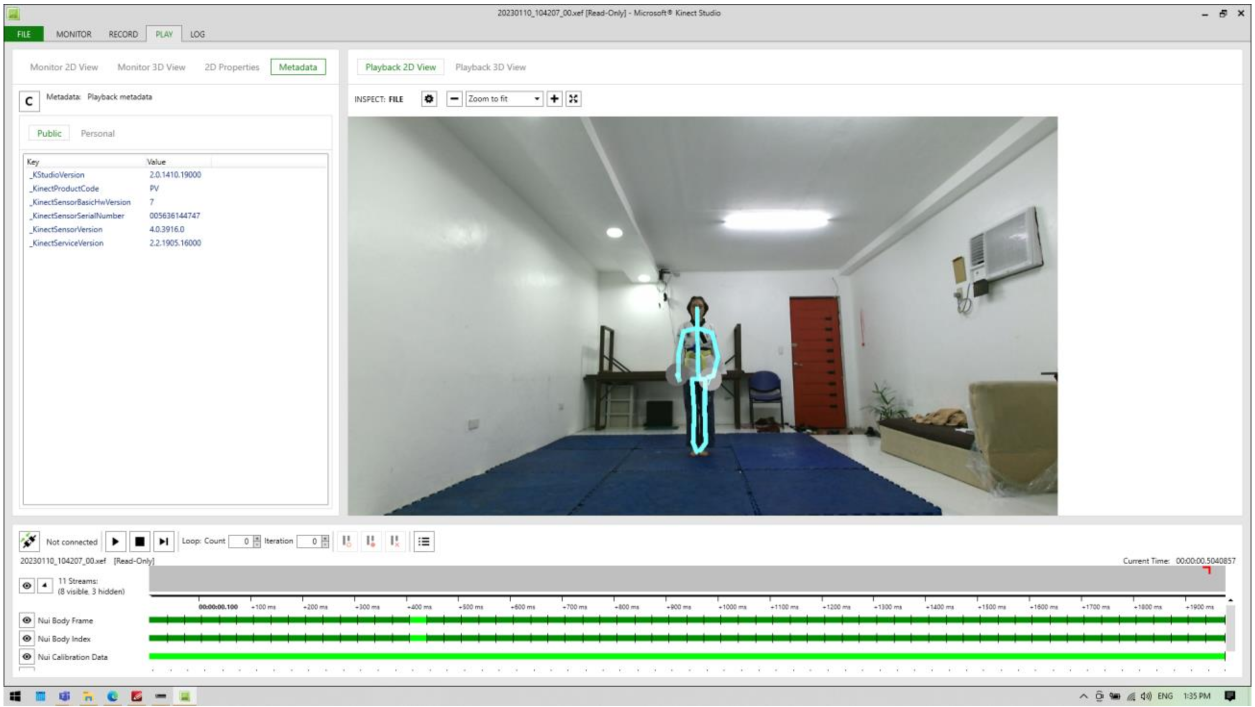


Figure I.19. Sample of Recording Process View

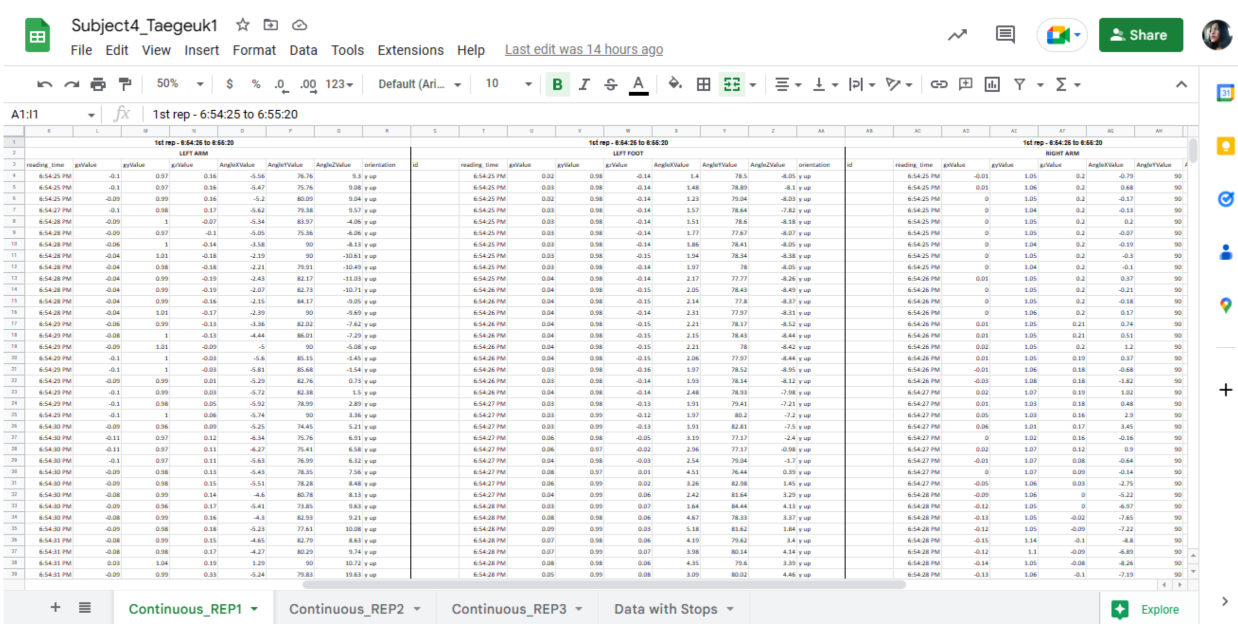


Figure I.20. Sample of the Recorded Dataset (from IMU)

Figure I.21. Sample of the Recorded Dataset (from Kinect)

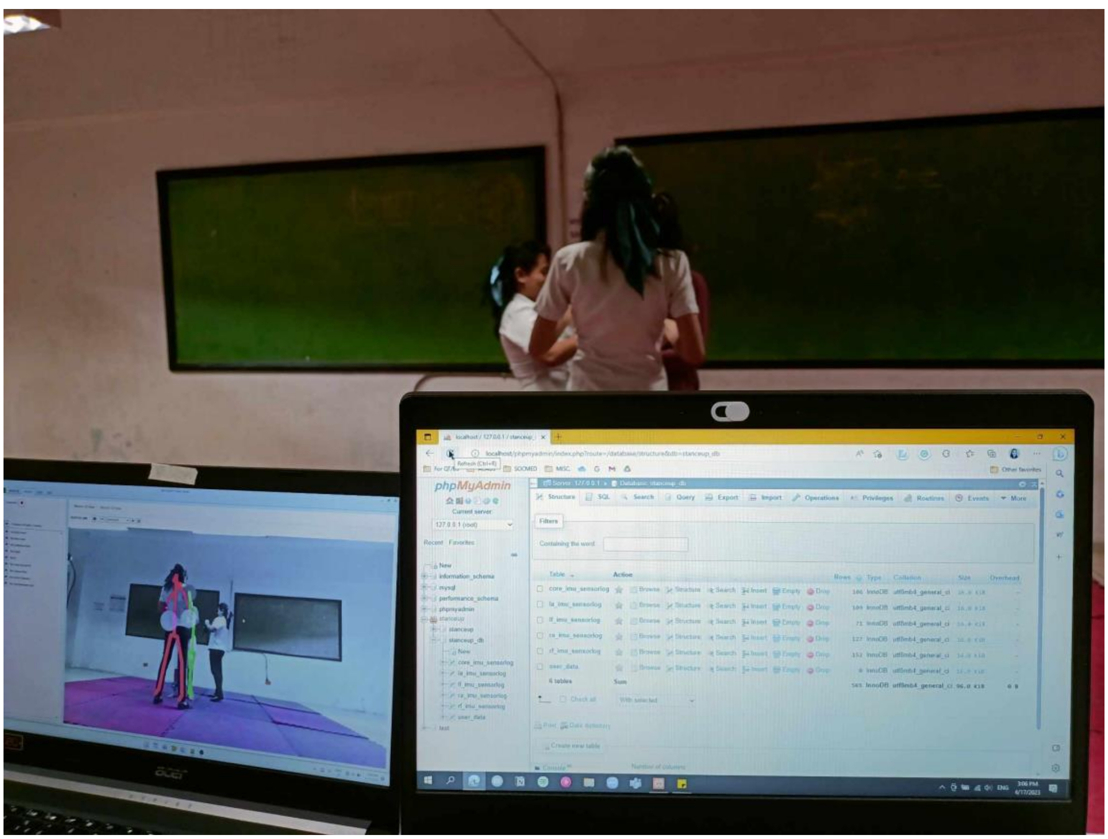


Figure I.22. Last Batch of Data Gathering Run

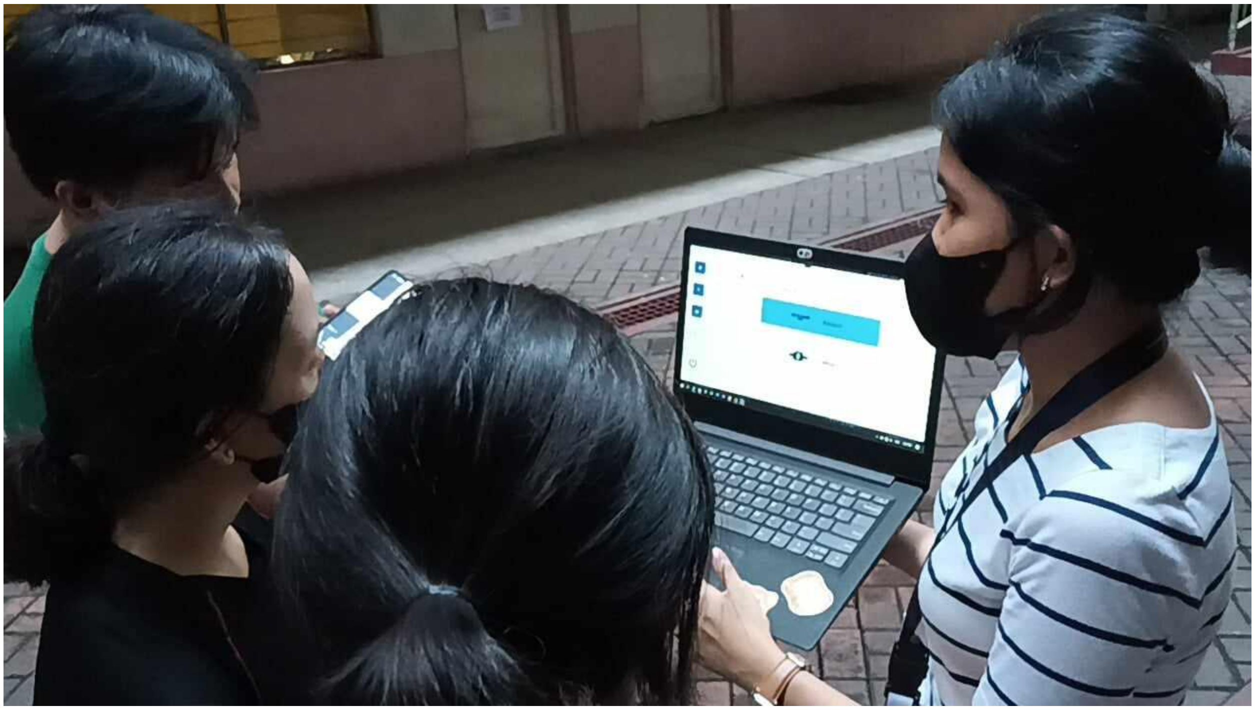


Figure I.23. Batch User Evaluation

DEFENSE SERIES

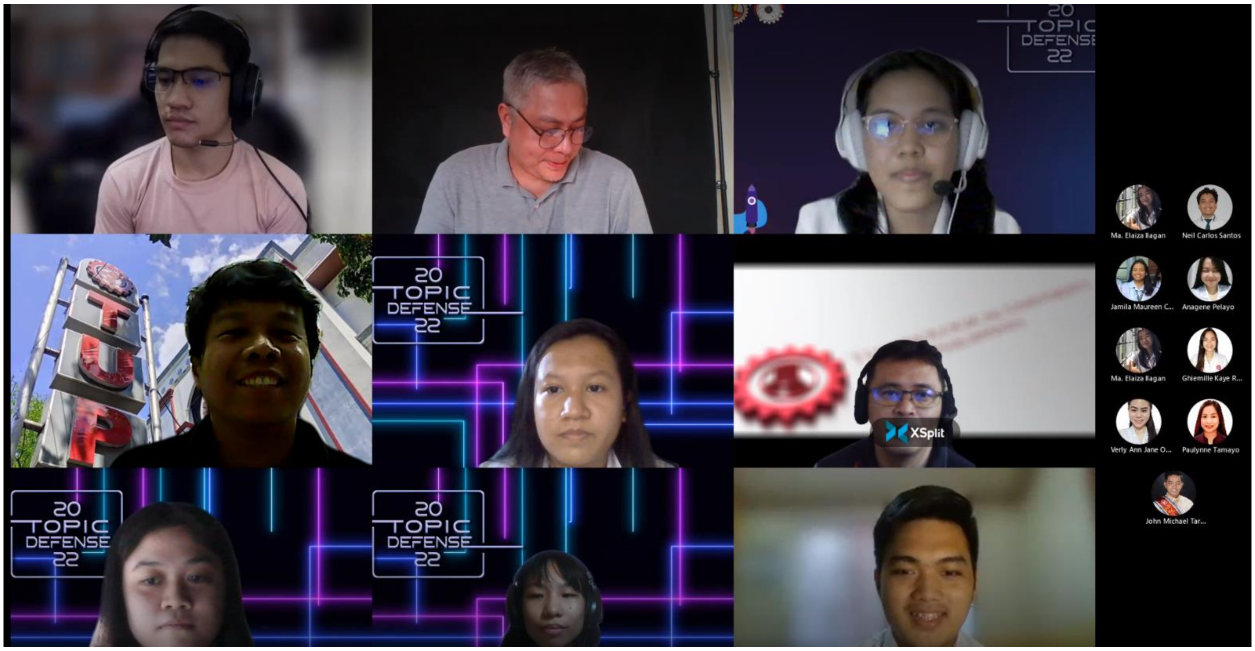


Figure I.24. Topic Defense (May 11, 2022)

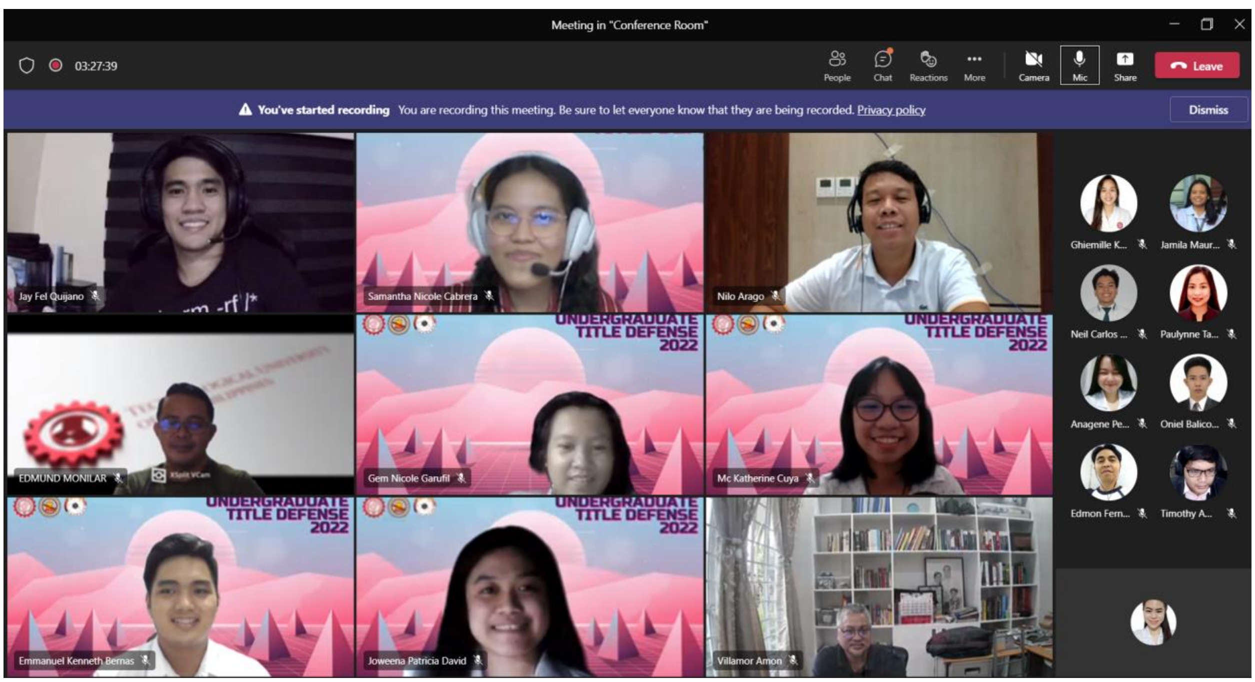


Figure I.25. Title Defense (June 28, 2022)


12:16
CABRERA
BERNAS
DAVID
CUYA


BERNAS

Figure I.26. Progress Presentation

Figure I.27. Pre-Final Defense (February 02, 2023)

Figure I.28. APPRECIATE

Figure I.29. Final Defense

Appendix J

Student Profile

Bernas
Emmanuel Kenneth R.

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emmanuelbernas@gmail.com
Blk 2 Lot 13 Antioch St. Pleasant Hills Subd. Brgy. San Manuel
San Jose del Monte, Bulacan

ABOUT ME

I am Emmanuel Kenneth R. Bernas, a consistent student leader since my primary school days. Aside from participating in extracurricular activities, I always make sure that I do not forget my academic responsibilities and strive to learn how to manage my time effectively.

EDUCATION

Tertiary Education August 2019 - August 2023
Technological University of the Philippines - Manila
Bachelor of Science in Electronics Engineering

Senior High School Education August 2019 - August 2023
Spirit of Joy School
Science, Technology, Engineering and Mathematics

Junior High School Education August 2019 - August 2023
Spirit of Joy School
Grade 7 to Grade 10

Primary Education August 2019 - August 2023
Spirit of Joy School (Grade 2-Grade 6)
Sienna College of San Jose del Monte, Bulacan (Grade 1)

WORK EXPERIENCE

Student Intern **January 2019 - March 2019**
RC Tollo Surveying
Ground topography encoder

Student Intern **August 2023- September 2023**
University of Perpetual Help System DALTA, Las Piñas Campus
Assisted in the control center for the nano-satellite. Assemble sinal antenna and other satellite communication related device. Monitor signal from the satellite and the ground station

SKILLS

- Leader
- Objective
- Fast Learner
- Time management and organization
- Effective Communication
- Critical Thinker

AWARDS/CERTIFICATIONS

VALEDICTORIAN SENIOR HIGH SCHOOL
2019

LEADERSHIP AWARDEE
SG PRESIDENT 2018-2019

BEST RESEARCHER
2019

Manila Youth Parliament
2023
BEST COMMITTEE PRESIDING OFFICER
MOST OUTSTANDING DELEGATE
MOST PRODUCTIVE

AFFILIATIONS

University Student Government
2020-2021
EXECUTIVE SECRETARY - COE
2021-2022
PRESIDENT

University Integrity Crusaders
2022-2023
PRESIDENT

COE - Appreciate 2023
2022-2023
CHAIRPERSON, APPRECIATE PUBLICITY, SPONSORSHIP AND MARKETING COMMITTEE

CABRERA
Samantha Nicole S.

09686022897
samcabrera04@gmail.com
8453 Trabajo St., Brgy. Olympia, Makati City

ABOUT ME

Dedicated and knowledgeable aspiring ECE Board Passer with software and data engineering-related skills. Adapts quickly to changing need and continuously pursuing ways to help others. Excited about the opportunity to take next career step with technology- and data-driven companies.

EDUCATION

Tertiary Education August 2019 - August 2023
Technological University of the Philippines - Manila
Bachelor of Science in Electronics Engineering

Senior High School Education July 2017 - April 2019
Makati Science High School
Science, Technology, Engineering and Mathematics
Graduated with Honors

Junior High School Education June 2013 - April 2017
Gen. Pio del Pilar National High School
Completed with Honors

Primary Education June 2007 - April 2013
Jose Magsaysay Elementary School
Graduated as First Honorable Mention

WORK EXPERIENCE

Technicians' Apprentice **August 2022 - September 2023**
Stelsen Integrated Systems Incorporated

- *Learned various auxiliary systems like FDAS, CCTV, PA/BGM, and INTERCOM through assisting technicians in their maintenance/inspection, installation, and troubleshooting services.*
- *Assisted the sales and operations department through strong clerical abilities.*
- *Applied and expanded upon education through hands-on-work with real world teams.*

SKILLS

- Web Development (HTML, CSS, JS)
- Database Management (SQL, PHP)
- Arduino Programming (C++)
- Data Analysis and Visualization (Python, R)
- Technical and User Support
- Clerical Support (Microsoft Office)
- Time Management
- Leadership

AWARDS/CERTIFICATIONS

Top 9 Best Booth - APPRECIATE 2023
May 2023

Best Research
April 2019

Writer of the Year
April 2017

AFFILIATIONS

Organization of Electronic Engineering Students
September 2019 - Present | MEMBER
September 2021 - 2022 | Secretary - General

Trendsponder - TUP ECE Publication
September 2022 - 2023 | Associated Editor

Elevate - Manila (Christian Youth Org.)
2020 - Present | Programs Ministry Volunteer

CUYA
MC KATHERINE P.

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cuyamckatherine@gmail.com
751 A-H, Unit C, Sgt. Bumatay St., Plainview, Mandaluyong City

ABOUT ME

A fourth year Bachelor of Science in Electronics Engineering student at Technological University of the Philippines - Manila. Currently the Finance Officer of Graduating Class and of the Electronics Engineering Students in TUP-Manila for the academic year 2022-2023. She's also the Finance Chairperson of the APPRECIATE 2023.

EDUCATION

Tertiary Education August 2019 - August 2023
Technological University of the Philippines - Manila
Bachelor of Science in Electronics Engineering

Senior High School Education July 2017 - April 2019
Manuel S. Enverga University Foundation
Science Technology Engineering and Mathematics (STEM)
Graduated with High Honor

Junior High School Education June 2013 - April 2017
Atimonan National Comprehensive High School
Special Science Class
Completed with High Honor

Primary Education June 2007 - April 2013
Atimonan Central School
SPED-FL
Graduated with Honors

WORK EXPERIENCE

I&C Engineering Department Intern
July 2022 - September 2022
MHI Power Technical Services Corporation
Intern in the Instrumentation and Control (I&C) Engineering Department.
Assist in creating Netmation Database, Graphics, Logics, and Human Machine Interface (HMI) of the system of a project.
Assist in modification of the Control Screen of the plant site
Assist in modification of the Logic sheets of Analog and Digital Input for Wastewater Treatment System.

SKILLS

- Knowledgeable in schematic and PCB designing and simulation software (Multisim, Cadence Virtuoso, Proteus)
- Has basic knowledge in Arduino C++, Python, HTML.
- Experienced in creating accurate financial forecasts and monitoring financial transactions.
- Skilled in preparing financial statements and conducting financial audits.
- Efficient in MS Office

AWARDS/CERTIFICATIONS

TOP 10 Best Booth - APPRECIATE 2023
May 19, 2023

AFFILIATIONS

Organization of Electronic Engineering Students (OECES)
August 2021 - July 2022
Vice President for Finance

OECES - Graduating Class Division
August 2022 - July 2023
Treasurer

DAVID
JOWEENA PATRICIA P.

09162578344
joweenadavid@gmail.com
Blk14 L8 Ph3, Citta Italia, Mambog 3, Bacoor, Cavite

ABOUT ME

A Fourth Year student taking Bachelor of Science in Electronics Engineering, major in Emerging Technologies in the Technological University of the Philippines-Manila. Aims to further enhance her knowledge and skills in the Electronics Engineering field to be able to become an electronics engineer while gaining valuable work experience in a team-oriented environment.

EDUCATION

Tertiary Education August 2019 - August 2023
Technological University of the Philippines - Manila
Bachelor of Science in Electronics Engineering

Senior High School Education July 2017 - April 2019
University of Perpetual Help System Dalta - Molino
Science, Technology, Engineering, and Mathematics (STEM)

Junior High School Education June 2013 - April 2017
Imus Institute of Science and Technology
Business High School
Graduated with Honors

Primary Education June 2007 - March 2013
St. Jerome Emiliani Institute (Grade 6)
Graduated as Salutatorian
United International Private School (Grade 2-5)
Statefields School Inc. (Grade 1)

WORK EXPERIENCE

Student Intern (Power and Electronics Engineering Dept.)
August 2022 - September 2022
Integrated Research and Training Center - TUP Manila
- *Mainly performed laboratory experiments and accomplished write-ups about the conducted activities.*
- *Experiments included the use of Arduino and electronic components. Fiber optic fusion splicing was also performed.*

Visual PCB Inspector
January 2019 - February 2019
Creotec Philippines Inc.
- *Main role was to check if the electronic components mounted on each board were placed in the right position.*

SKILLS

- Web/Desktop Development (C#, HTML, CSS, JavaScript)
- Arduino Programming (C++)
- Data Analysis (MATLAB, R)
- Microsoft and Google Suite
- Video and Image Editing (Canva, Adobe After Effects)
- Time Management

AWARDS/CERTIFICATIONS

Top 9 Best Booth - APPRECIATE 2023
May 2023

IP Addressing and Subnetting for CCNA
May 2022

AFFILIATIONS

Organization of Electronic Engineering Students
August 2019 - August 2023
Member

Institute of Electronics Engineers of the Philippines Manila Student Chapter
August 2019 - 2021
Member

GARUFIL
GEM NICOLE A.

09153546642
garufilgn@gmail.com
197 Lilac St. Panghulo, Obando, Bulacan

ABOUT ME

A graduating Electronics Engineering student from the Technological University of the Philippines – Manila passionate about exploring the intersection between technology and the human body to help people have a greater understanding with themselves; aiming to learn new things to reach this vision.

EDUCATION

Tertiary Education August 2019 - August 2023
Technological University of the Philippines - Manila
Bachelor of Science in Electronics Engineering

Senior High School Education June 2017 - March 2019
San Diego Parochial School
Science Technology Engineering and Mathematics (STEM)
Graduated with High Honors (Salutatorian)

Junior High School Education June 2013 - March 2017
Panghulo National High School
Graduated with Honors

Primary Education June 2007 - March 2013
Panjolo Elementary School

WORK EXPERIENCE

Research Intern (SmartLab & PERPSAT)
August 2019 - August 2023
University of Perpetual Health DALTA System - Las Pinas
- *Assisted in the additional features added in the website application (image input, messaging). Assists in applying the remote accessing process in the server.*
- *Learned about Orbitron for satellite tracking and created an easier-to-understand diagram for the connections needed in building the base of the PERPSAT ground station.*

SKILLS

- Data Analysis (Python & MATLAB)
- Web/Desktop Development (HTML, CSS, C#, JavaScript)
- Data Management (SQL, SQLite)
- C++ (Arduino Programming)
- Linux (Raspberry Pi OS)
- Microsoft and Google Suite
- Adobe Suite (Ps, Id, Ai)

AWARDS/CERTIFICATIONS

Top 9 Best Booth - APPRECIATE 2023
May 2023
IP Addressing and Subnetting for CCNA
May 2022
Research and Innovation Awardee - Silver medalist
March 2019

AFFILIATIONS

Organization of Electronic Engineering Students
September 2019 - Present | MEMBER
September 2021 - 2022 | Documentation Committee Manager

Trendsponder - TUP ECE Publication
September 2022 - 2023 | Editor-in-Chief

DOST Scholar's Club (TUP – Manila)
September 2019 - Present | MEMBER