Mobile Full-Body Tracking

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CSE 145 / 237D

Introduction:

We plan to create a full body tracking system that can track the location of the torso and two ankles. Full body tracking systems have many use cases such as virtual reality and rigging for CGI video productions. There are several existing techniques that deal with tracking; however current methods have severe limitations which we aim to address.

The first and most common body tracking method is visual tracking where the users wear several reflective markers on the body that is seen by an external capture device such as a camera. This capture device is able to then take the location of where each marker is and calculate the body location. Despite this being a commonly used method, there are major limitations including a steep initial setup cost, time, and labor as well as a limited capture space. This is compounded by occlusion, or broken line of sight between the capture device and person which creates the need for even more capture devices.

The second method is using several very accurate inertial measurement units (IMU) and estimating body movement. This has advantages over visual tracking where the user does not have to consider the location of capture devices. However, its core disadvantage is the accumulation of error over time. In order to attain the position of the body, an integration needs to be done relative to acceleration which causes positional drift to occur after around 5 to 10 minutes. Some companies have used high-precision IMUs to address this issue but such devices are expensive and still prone to error after enough time.

Our project plan is to improve on both solutions by using ultra-wide band trackers. Moreover, we plan to use ultra-wide band emitters and receivers to create a closed loop system - that is, a system that uses multiple sources of data to implement robust error correction - minimizing the IMU error build up and greatly extending the possible capture time. This will also allow a user to operate in any space without the need for prior set up and any associated costs.

Technical Details

Currently, we are fortunate to be in contact with the UCSD research group, Wireless Communication, Systems and Networking (WCSNG), involved with ULoc, a research paper that utilizes ultra wideband (UWB) trackers to determine positions in world space with an estimated accuracy of 5 to 10 centimeters.

Both our project group and WCSNG found this to be best for our goal in implementing full body tracking due to the accuracy in comparison to wifi-triangulation, which has an accuracy measurement of 1 to 2 meters. Thus, our project is able to take advantage of the hardware that the research team is using, including their custom-made UWB tracker and receiver boards alongside the HTC Vive virtual reality (VR) headset. In order to achieve UWB tracking, they utilize 4 different access points designed to detect a tracker board in which such precision is possible through phase differences in the frequency space. When each Decawave module determines the UWB signal transmitted by the tracker, the data is transferred as small chunks of the measured frequency space obtained to the Raspberry Pi 3 so that the USB interface does not become overwhelmed by the amount of data coming from the access point. From this, the Raspberry Pi can then process this information using knowledge about the distance of each Decawave on the board to get an azimuth and elevation metric, alternatively worded as the direction of the source signal. From this, each of the 4 Raspberry Pis can then transmit each of their tracker information to a host server, where it then triangulates the position of the UWB tracker in world space. The current limitations involve the fact that the trackers have only been tested for leg tracking and that it is only reliant on UWB to determine the tracker's position in local space. The project group believes that in using HTC Vive controllers, they can act as trackers in addition to the use of UWB for full-body tracking. As for the reliance on UWB, no other component is there to assist in accuracy with WCSNG's progress at the moment. With the hardware description in the next section however, we plan on using an inertial measurement unit (IMU) within a stretch goal to improve this metric.

For ULoc's current hardware specifications, the research group has on their trackers the Decawave UWB chip (DW1000), an ESP8266 for wireless communication, and the inertial measurement unit MPU6050 chip with 6 degrees of freedom. The tracker itself also has an internal LiPo battery and a USB C port for charging and data collection from the board. On the access point, there is an array of DW1000 modules to facilitate the UWB tracking as well as a micro-B port for connecting it with a Raspberry Pi. It also has a clock distribution tree in order to synchronize the Decawave modules for accurate ranging between it and the trackers. Nevertheless, both the tracker and access point are controlled with an STM32F107 chip in which the team has the firmware for their specific purpose. With the inclusion of the IMU, we foresee that the full body tracker can get additional information about the rotation of the component relative to the body and use sensor fusion with UWB data, allowing for increased accuracy. However, for the MVP, we aim to implement the full-body tracking using inverse kinematics (IK) and the skinned multi-person linear body model (SMPL), which are algorithms that estimate a person’s body motion through the use of points in world space.

The vision to complete the minimum viable product on time is accomplished by being in constant contact with our mentors on this UWB implementation and using the models suggested such as IK and SMPL. To achieve this, our group has decided to meet asynchronously in order to maximize the amount of time on working with this project. We foresee that this will take time to understand and implement as the basis is rooted in research and so we plan on doing rapid software development since it represents the majority of this project.

MVP

The Minimum Viable Product (MVP) for the quarter will be a limited implementation of the IMU-UWB rigging system with generally accurate body position. The system should be able to allow a user to continuously rig a partial model with their own movements with low error. We define low error as visibly close representation of the user's action between the predicted model and ground truth.

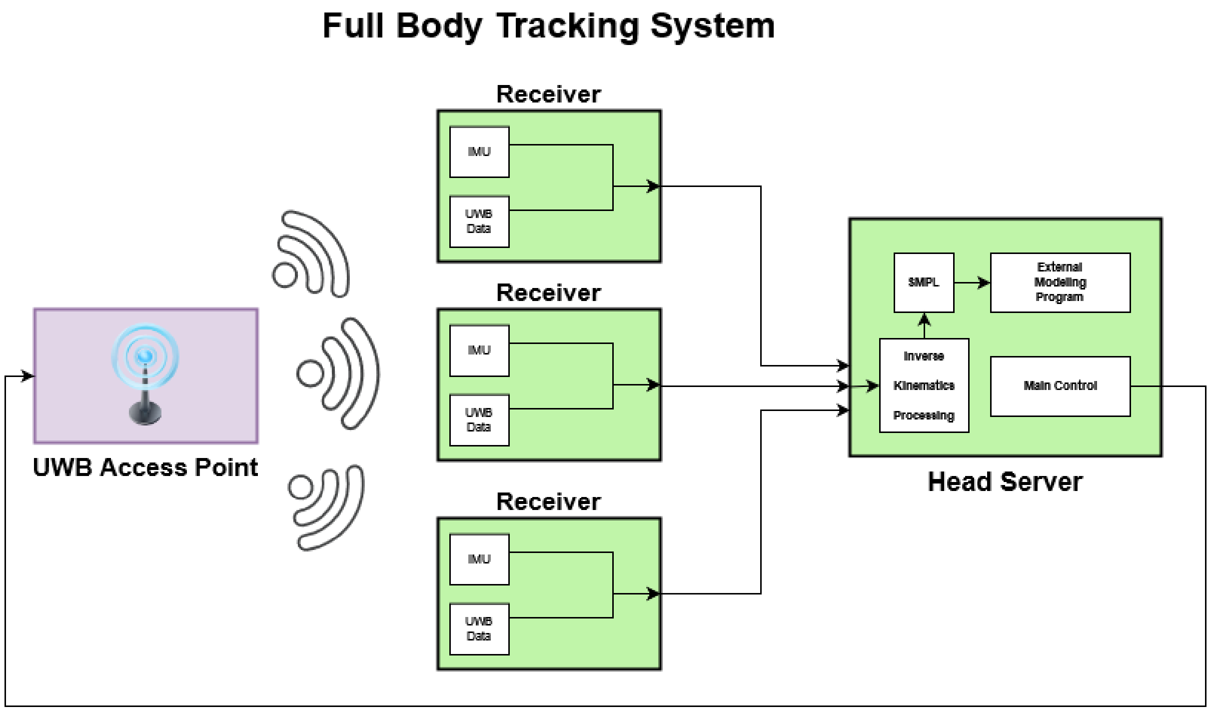

Figure 1: High-Level System Diagram

Our system will consist of four UWB access points arranged in the corners of a testing area (roughly 3m-4m) and at least three reciever modules that will allow us to rig a user's legs as part of a model - a known issue for companies interested in mobile VR technology such as Facebook. These reciever modules will be anchored at a users waist and ankles.

A successful MVP will be able to visually display a rigged model and allow user feedback on the accuracy of the tracking system. In addition to user testing and feedback, we will be using the VIVE lighthouse system to act as a ground truth system.

The main limitations of this MVP will be the bulkiness of the system. The data collection system will be hard mounted in the room for testing purposes and the wearable modules will likely be bulky and uncomfortable. Later iterations would focus on miniaturization and form fitting mounts for the user.

Additional room for improvement would include mobile access points and additional receiver modules for the arms.

Risks, Roadblocks, and Feasibility

As a whole, we know that each of the major components in the system are feasible product that have reached market before. Due to the short timescale, our larger risk falls on the development time for these systems. Namely, there are four major points of failure for this project - the configuration, the middleware, the IMUs, and the integration of the SMPL system.

The initial configuration and middleware errors may cause the system to fail and crash in unforeseen ways and could dramatically extend development time. Moveover, these two components are linchpins of the system and thus could halt development of other features in the system. Thus, this is our highest priority task. With this said, these two processes are our more standard tasks (flashing firmware to our Raspberry pi boards and ensuring that our data pipeline is properly defined for our middleware developers) and so we do expect these processes to be fairly

The IMU system both may have hardware failures and firmware issues that may require more development or replacement of those systems. These IMUs are fairly cheap and replaceable and, moreover, we aim to start with a smaller initial amount of modules than the final product before scaling up to reduce the error space for our system.

The SMPL system is the final major failure point and largely consists of any unforeseen limitations of the system. We are starting with a few tests to evaluate the capabilities of the system and make adjustments as needed - up to and including finding alternate models. With this said, this process is somewhat standard and we expect to find a feasible alternative if need be.

Group Management

The major roles in our team's management consists of three extra roles. The first being the spokesperson, the one who's in leads the communication with the inter relations of the group, those being the research PI & graduate mentor we are working for/with, and the class Professor & TA. We then have our meeting planner & meeting lead. The planner is responsible for scheduling the weekly meetings we will have & with each meeting the meeting lead would be in charge of keeping tabs with the milestone's deadlines & making sure everyone is keeping pace.

For the overall decision making, we agreed on having a majority consensus with the exception of ties being broken by the decision of the person responsible for realizing that decision. We have secured 2 main modes of communication: One with intragroup communication and the other with intergroup communication(with the research PI/mentor). They are held on Discord & Slack respectively.

We will refer to the Gantt chart that we created below and serve it as the ideal timeline for this quarter. In the event of schedule slipping, we concluded on a workflow on mitigating the issue. The first check would be whether the one responsible for the milestone just isn't performing well, which would translate to a meeting and discussion on what's wrong and if the others could possibly help out. If the issue isn't resolved by just the group members, we would turn to the mentor of our group for advice on solving the issue at hand. Lastly, with even the mentor's help the issue remains, there will be a discussion on resolving how the rest of the project could work without the said milestone. For those milestones we organized it in this way, the initial milestone of getting the setup running will be having everyone working on it as it is the one major priority milestone that needs to be finished before we can tackle the rest of the milestones. As for the next milestones, as they all don't need personnel working on them immediately like the previous one, we have yet to decide who's role it is for the Sensor Fusion, Position Locality, Body Posture Estimation, & SMPL integration milestones yet.

Project Development

For the technical end of the project, we have several roles to ensure a smooth journey to success by the end of the quarter. We have the embedded software lead, who is handled by Danny, which details the work surrounding the hardware/firmware of the set-up. Next we have the webmaster role, which Anh handles, who is going to be the main developer for the website deliverable of the project. Next we have the embedded engineer, which is responsible for the efforts behind the creation of middleware, handled by Michael. Lastly, there is the algorithm lead, who is tasked with the creation of the algorithm needed for the SMPL, taken by Branson.

For the specific hardware, we are planning on using the raspberry pi's, the WCSNG's ULOC Anchor v5, & a linux server. Currently, we are thankful for the WCSNG to have allowed us to borrow this hardware for the purpose of the project. On the software side, we will be utilizing the ROS, python, & a game engine/rendering software. For these all are open to use for everyone hence all is available to us without monetary investment.

For testing, we will conduct user testing - directed with instructed and uninstructed motions - with feedback from users to identify issues in usage. In addition, we will have the VIVE lighthouse available to verify the measurements. For documentation, we will be using github as our foundation to log our developments and changes throughout the quarter.

Milestones

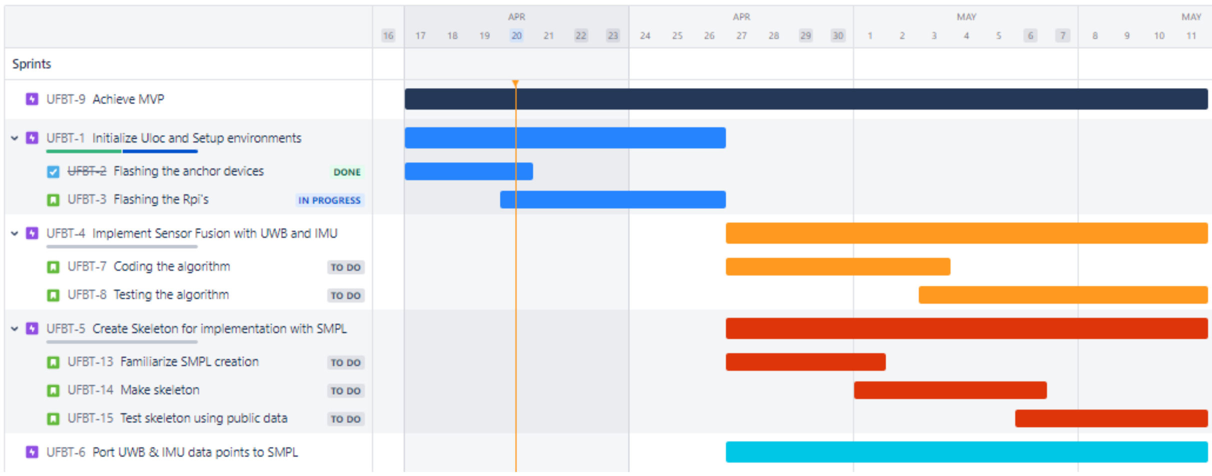

Figure 2: MVP Milestones

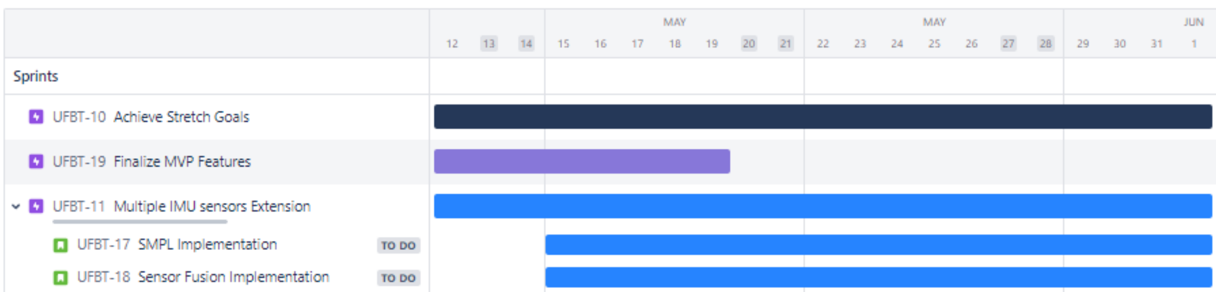

Figure 3: Stretch Goal Milestones

As seen in figure 2 and 3, we have generated a gantt chart to track our milestone progress and task assignments.

Milestone assignments are allocated below:

Milestones	Group Member(s)
• Initialize ULOC and Setup Environments	Everyone
• STM32+IMU Setup	Anh
• Implement Inverse Kinematics	Branson
• Integrating UWB Error Correction	Branson
• Create Skeleton for SMPL	Branson
• Port Sensor Data to SMPL	Michael, Danny

• Finalize/Debugging MVP	Everyone
• Multi-IMU Extension; SMPL	Michael, Danny
• Multi-IMU Extension; Sensor Fusion	Branson, Anh

Associated deliverables should be:

Milestones	Deliverables
• Initialize ULOC and Setup Environments	Basic UWB localisation demo
• STM32 + IMU Setup	Read out of IMU data
• Implement Inverse Kinematics	IMU localisation demo
• Integrating UWB Error Correction	UWB/IMU demo
• Create Skeleton for SMPL	Rendering Basic Demo (Single Frame of Data)
• Port Sensor Data to SMPL	Rendering Mapped Demo (Getting Basic Samples from UWB)
• Finalize/Debugging MVP	Rendering Long Running Demo
• Multi-IMU Extension; SMPL	Long Running Demo with Arm Sensor feed
• Multi-IMU Extension; Sensor Fusion	Rendering Long Running Demo with Arm Sensors

Project Summary

- UWB, IMU, Wifi board determining / estimating body positioning
    - Parts:
        - MPU6050, Decawave, Wifi Chip
    - 4 corner of UWB detector boards with L shaped antennas and maximum
    - coverage of 5x5
        - Each have a raspberry pi 4
    - Utilize SMPL to estimate joint and body position with less boards
    - Boards utilize ROS
    - Goal: Sensor fusion of IMU and UWB to allow for body posture estimation
        - Wifi is only for communication with device managing posture
        - Raspberry Pi
- Verification using an HTC Vive with lighthouses
- Use cases:
    - Body rigging for films
    - VR
    - Mainly in outdoor situations
- Future stretch goals:
    - Miniaturize PCB
    - Optimize the communication between UWB device and receiver
    - On-person tracking
    - (stretched to infinity) Improved accuracy of UWB tracking using modified antenna