Vitruvian - Personal Training App

Inter-Departmental Senior Design

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II. Executive Summary

2.1 Executive Summary

While it is recommended to workout and widely accepted that working out increases one's health, it is often difficult to know how to start. Many beginners turn to social media fitness influencers, e-book programs, online videos, and/or personal trainers to start their fitness journey. While these resources can all instruct a user on what exercises to perform, they often do not accurately show a user how to perform the exercises and the proper technique to use to activate the correct muscles. The problem with using improper form is that there is an increased risk of injury as well as less than optimal progress. Our solution, Vitruvian, is an accessible, low cost product targeting individuals who are starting or who are already well into their fitness journey to provide them with technique feedback in order to reduce the risk of injury. The project consists of software and hardware components all encompassed within a users smartphone. The phone's camera will be used to record a user working out and a computer vision algorithm will use the recording to analyze an individual's skeletomuscular structure, and limb and joint positioning. The software will accurately determine an individual's technique by finding the angles between limbs and will provide technique correction feedback by comparing the individuals limb angles with medical data collected. The product will be accessible and have an easy to use interface for individuals with a smartphone.

Throughout the semester, the team went through many problem/solution iterations. The solution was originally an assistant drone that served as an embodied central intelligence, which was narrowed down to an assistant workout drone. After receiving much feedback and gaining a better understanding of requirements, the team determined that a drone was in fact not the best solution for the user we are targeting. Although we will be moving forward using a phone camera, we will still use the OpenPose software we implemented this past semester. The team was able to use OpenPose to detect limb positioning of multiple individuals and this positioning will be used to find the angle between limbs. While the team considered using a Kinect, it was determined that OpenPose would be sufficient for our solution because it makes using the phone camera easier and the lag associated with OpenPose is acceptable due to the fact that our product gives user feedback in between sets and not in real time. Although much of the teams progress this semester was made on the drone, we feel we are still in a good position to hit the ground running next semester.

Although this semester felt like a rollercoaster with a constantly changing problem/ solution statement, the team is excited to have a better defined problem and solution to work on next semester that is both innovative, challenging, and important. We were able to accomplish skeletal tracking using OpenPose and the team will continue to build off of this next semester. While there is a lot of work to be done including medical data collection, app interface development, and further refining OpenPose, the team feels that these goals are attainable for next semester.

2.2 Business Plan

2.2.1 Value proposition

Our product is a phone app that makes physical training healthier and more effective. If you use our product, you will reach your health goals faster and with ease.

2.2.2 Stakeholders

End consumers: It is particularly important to not give faulty advice to people in any medical context. While what we are proposing to do is a conceptually straightforward application, we will do our best to ensure accuracy. That being said, we must make it clear that our software's feedback, like the advice of many personal trainers, is strictly non-medical.

Researchers: We plan to get our posture health and optimization data from medical research. If this proves to be a problem, we can write a script to get recent data from relevant online public forums adjusted for perceived value in those forums.

2.2.3 Market research

There are 55 million health club members in the US. This includes those with memberships to gyms, studios, and other similar facilities. Each person in this group has already demonstrated substantial desire and willingness to pay for physical fitness and health. Given US statistics, we would strongly expect more than 50 million in this group to have access to smartphones.

2.2.4 Competition

There are numerous apps that suggest and help track exercises over time. Since this is not our value proposition, they are not direct competition. However, they are conceptually close enough that user confusion may lead them to believe that those apps are in fact competition.

Physical trainers, as mentioned numerous times in our report, exist. Our primary motivation can be boiled down to making the optimal physical trainer accessible to every individual. However, especially before product maturation, human physical trainers can react dynamically and give further personalized feedback than our product can. Given the tremendous difference in price, direct competition on the part of a physical trainer will be increasingly difficult and possibly unnecessary.

There are at least two apps that take advantage of computer vision to detect and analyze exercise form. In our research, we found them to be emulating social networks with a focus on the exercise as social-proof-of-work. While an intriguing idea, we found their exercise offerings to be limited and focus to be misplaced.

III. Overview of Project

While exercise and physical activity are commonly recommended by doctors and are known to enhance the health of an individual, there is always a risk associated with any form of physical activity. The most common cause of exercise related injury is improper technique. Technique is the way in which an individual performs an exercise to target a specific muscle group. The effects of improper technique include injuries such as strains or tears as well as slower than expected progress.

Individuals who struggle with improper form often turn to workout videos that they can follow along with or personal trainers who can correct their form in real time. While these solutions can improve form for some individuals, neither are a perfect solution for everyone. Workout videos do have professional trainers leading workouts; however, they often do not mention proper technique or what muscle group is being activated and so a user could be performing an exercise improperly without knowing. The limitation of personal trainers is that not everyone can afford to have a personal trainer or even has the time to meet a personal trainer at a gym. Because of the limitations to current solutions, there is an even greater need for Vitruvian, which is both cost effective and gives real time technique feedback.

Vitruvian is a low cost solution that uses a phone camera to record a user while working out. The quantitative information such as joint and limb positioning will be collected from the computer vision algorithm run on the phone camera video and compared against proper form to give the user position correcting feedback after each set. Feedback will be received through a smartphone application, which will visually display the proper form technique overlayed on top of the users last set thus showing the clear difference and form improvements to be made.

IV. Technical Description

4.1 Specifications and Requirements

The teams project aims to make healthy and effective physical exercise more accessible to as many people as possible. Therefore, the teams project needs to conform to the following specifications:

Functionality	Primarily, the software needs to be able to observe the user's movements while exercising in order to recognize, measure, and correct the movements. Thus, the project must be able to observe the user through the full exercise and give feedback during and after the exercise.
Cost	Given that higher cost alternatives such as personal trainers exist, and that the project's goal is to increase accessibility, the monetary cost to each individual user must be very low.
Interface	The interface must be nonintrusive and easy-to-use. Given that the project aims to increase accessibility, using personal phones as the interface makes the most sense.
Regulation	To avoid regulatory problems, the project’s feedback needs to remain in a non-medical advisory state.

Ergonomics	Given the choice of interface, the ergonomics of the project mainly concerns dynamic sensor placement such that the sensors can effectively observe exercises. Stationary sensor placement will not be a concern of ergonomics. **Phones**: Since possible phone placement will vary greatly on a case-by-case basis, we need to make sure that the software works effectively with many different phone positions. Ultimately, we will direct the user through the interface for phone placement, and the baseline positions we determine must work particularly effectively. **Wearables**: Unlike phone placement, we can specify wearable placement relative to the body. Since wearables will be on the body during physical exercise, they must be light and avoid limiting the user’s movements.
Accessibility	The monetary cost, cognitive burden of using the solution, and interface complexity must be minimized.

4.2 Iterations and Alternative Solutions

The team went through numerous alternative solutions to solve the problem of monetary and epistemic inaccesibility of healthy and effective physical exercise. The primary alternatives are as follows:

Physical Trainer Drone - By using a small autonomous drone to dynamically observe the user while they exercise, the possible problems that can stem from poor camera placement can be solved. In addition, the mobile camera allows for the project to also be used for outdoors sports and non-stationary exercises. The user's phone would still be the primary interface except for the camera.

Facility-installed Physical Trainer Software - Instead of creating a phone application that every user would use individually, the team can create a project that would be used by a facility (such as a gym) or a sports team. In this solution, a small number of stationary sensors (be it 2d or 3d cameras) would observe multiple people simultaneously, the software would track them through their movements and create performance/correction reports, and this analysis would be used as a part of the facility's offering or as an addition to the existing expertise in a sports team.

Physical Training Regimen Creator - This solution would not only observe and correct exercise movements, but also create a dynamic regimen based on user input and ongoing movement observations. Software that recommend and track regimens already exist, and the challenge with this solution would be to meaningfully utilize the software's observations in order to modify the regimen. In effect, this would mean a very close analogue of the thinking process of a physical trainer.

Wearable sensors as observation tools - In this solution, the team would use wearable sensors with accelerometers in order to create an accurate 3d reconstruction of the user's movements. The sensors would be cheap and possibly more accurate than 2d camera inference. A possible combination would be to use this in conjunction with camera observation.

3d cameras as observation tools - In this solution, the team would use a 3d camera like a Kinect to observe the user's movements. Given the depth data that accompanies the 2d image in such a setup, the software's reconstruction of movements is expected to be more accurate than using 2d images.

3d cameras as 2d model training tools - In this solution, which could be coupled with most of the others, the team would use a 3d camera to further train the machine learning model that the 2d cameras would later use. This is expected to increase the accuracy and consistency of the final product.

4.3 Technical Description and Approach

The team desires a solution that is highly accessible to the end user and is able to make sufficient observations with low cognitive overhead to the user. That is to say, the team aims for the solution to be non intrusive so that the effort to use it would not dissuade its use. The team analyzed our possible solutions with this and the above specifications in mind.

The team found that the use of a small drone as the observation tool was an insufficient solution for this specific problem. Low battery life, intrusive use, and the additional cost all make that solution a poor choice if the only goal is to make healthy and effective exercise more accessible. Like a drone, a 3d camera is also a poor fit for a specialized solution given its additional cost and use burdens.

Regimen creation and recommendation apps already exist. Unless we can meaningfully use the observation and reconstruction data to modify the recommended regimen, any solution the team delivers will be unoriginal and likely less effective.

A group solution for businesses or teams remains the most intriguing alternative. Ultimately, limiting the usage to physical spaces or organizations is counterintuitive given the teams goals for accessibility.

The use of wearable sensors would require many of them to be attached to specific parts of the body at the start of every training period. The team determined that this would go against the specifications outlined in Accessibility and, to a lower extent, Cost. Therefore, we considered using resources that users would already have access to.

With our need for high accessibility and low cost, using the personal phone as the main driver of the project is a natural conclusion. Almost everyone has phones. Given the project's goals, the team would expect an even higher percentage of the targeted demographic to have phones, if not all of them. The onboard camera and increasingly high processing power of these devices would also mean that we can entirely contain the hardware requirements of the project within a single, highly accessible device. The use of 3d cameras for training depends on our future tests where we determine the need for increased accuracy. A diagram of the software and hardware components of our project can be found in Figure 1.

4.4 Current status of the project and preliminary test results

Currently, the main pieces that have already been developed for our overall design are the limb detection algorithm, testing drone functionality, and market research. The limb detection program involved adapting the original OpenPose algorithm to work in Tensorflow and can currently run on our laptop's webcam. We still need to integrate this algorithm using a phone's camera instead of a webcam, but we believe this is doable within the beginning of next semester. We also spent the majority of the semester on developing a Tello drone to move around with given commands from a computer-based central system, but we ultimately decided to scratch the drone due to its limited functionality in terms of battery life and additional complexity. Furthermore, we researched other competitors within our field to focus on factors that differentiate our solution from current solutions. We concluded to focus on our algorithm and correcting different exercise forms accurately. In order to show quantitative results, we will test the accuracy of our limb detection algorithm running on a phone by physically measuring joints and compared to the measurements from our program.

4.5 Conclusion

We aim to create a low-cost, highly accessible solution to solve the problem of monetary and epistemic inaccesibility of healthy and effective physical exercise. Advances in neural networks and the capabilities of smartphones allow us to seamlessly take advantage of devices that our users will be familiar with and have access to. Using the phone as the sensor and interface, we can create a solution that fits our specifications and sufficiently reduce the problem to a primarily machine learning problem we are readily able to tackle.

V. Self-learning

5.1 Areas of learning

The main subject areas involved in our project are computer vision programming, phone app development, and working with new software. For implementing the limb algorithm program, we had to have a better understanding of computer vision by reading research papers within the field. Some group members had prior experience in this field which made it easier to use computer vision tools such as OpenCV. We also had to learn how to use different software in Linux such as Tensorflow, Python, and Anaconda; although it took some time to learn, we were able to develop enough of an understanding in order to implement the limb detection correctly.

We have yet to start teaching ourselves phone app development, but we have enough experience in programming to be able to learn this tool quickly and effectively next semester. If we decide to use 3d camera models such as the Kinect to train a phone's 2d camera, we will also need to familiarize ourselves with machine learning. Half of our team has done some form of machine learning before, but we believe that this will be more difficult than our prior experiences so we hope to learn through the help of our advisor.

5.2 Useful classes and prior knowledge

In terms of classes beneficial for our project, Chloe and Abe’s experience in their Foundational Data Science course helped streamline our limb detection program. Hal’s background in different computer science courses has helped us figure out how to plan out our system design through phone apps, machine learning, and programming. Ajmain’s prior research in the GRASP Lab taught him about computer vision, machine learning and drones, which helped up to get the limb detection program running in Linux. Having experience in OpenCV and Tensorflow helped us integrate different subject fields of our project into one solution.

5.3 Feedback

Throughout the semester, the team has received continuous feedback from peers and instructors alike about how to modify our project and our product to be as useful and successful as possible. While critical feedback is not always easy to receive, we have found it to be a crucial element of our design process and have found ways to incorporate much of it into our product.

One of the most useful pieces of feedback that the team received was to narrow down the application of our product to a specific use-case for a specific market. Our product was originally an artificially intelligent all-purpose drone personal assistant. While our peers and instructors found this to be ambitious, they also felt that it was not specific enough and needed to be narrowed down in order to find a specific problem and a specific type of user. After receiving this feedback, our team discussed at length various ideas that we felt we could incorporate into the drone interface. Eventually we landed upon a problem statement that we were all passionate about, improving personal fitness, and a solution that would change our all-purpose drone personal assistant into a drone personal trainer for everyday people to use. This gave us a bit more clarity about what our product would look like and who it would be for, however we have since incorporated much more feedback.

A piece of feedback that we received that we disagreed with initially was the idea of removing the drone from our product. During our various presentations to the class and through our demo days, we were asked to evaluate whether the drone was really useful to solve our problem statement, and whether it was actually adding unnecessary complexity to our solution. At first we were very hesitant to remove the drone, since we were passionate about it and saw it as a futuristic and novel addition to our project. After various discussions with TAs and among ourselves, however, we decided that it was not the best solution to our problem, and that much of the feedback we received was valid and helpful. Since then, we have moved away from the drone and, with our current solution, have a much simpler yet more practical product for our problem statement. While it was difficult for us to accept the feedback initially, it has led to a more robust and realistic solution.

VI. Ethical and Professional Responsibilities

6.1 Global/Societal context

Our project is geared towards promoting fitness and a healthy lifestyle. We believe that most individuals understand the importance of staying healthy and how exercise is vital to that goal, but there are many factors that inhibit individuals from exercising. These factors include the cost of going to the gym, lack of knowledge, and need for instruction. Our project hopes to reconcile these factors by making exercise accessible for anyone; the only thing you will need is a phone. Within a societal and global context, our project can work anywhere and for anyone as long as they have a phone that can meet the requirements to run our app. We hope that this will get more people interested in getting into exercise, which will make our society healthier. In terms of environment, there are not too many implications related to our project, but using our exercise app indoors will reduce transportation costs and related emissions from driving to the gym everyday.

6.2 Potential ethical issues

The main ethical issues we face are related to data and privacy-related concerns. Our app records videos of people performing exercises with their faces as well as keeping any personal information needed to register accounts or other similar concepts. In order to resolve these issues, we plan on encrypting personal information. In regards to videos, we do not plan on storing any videos after their original use because we only need the videos for immediate processing to give real feedback to users during exercise routines.

VII. Meetings

Throughout the semester, the team properly utilized their advisor, Pratik Chaudhari, as well as the teaching assistant staff and professors. The team first met with Professor Chaudhari in the middle of September to discuss the project focus, potential challenges the team would face, and potential solutions. We had determined that we would use a drone for activity recognition and the team left the meeting with next steps to accomplish in the next month. As the application of the drone narrowed, we maintained email communication with Professor Chaudhari in order to not only keep him informed in our design iteration process, but to also consult him about technology and potential solutions. We met with Professor Chaudhari again in November to discuss the progress we had made in October, the pivots we made, and how to move forward. Next semester, we plan to meet with Professor Chaudhari bi-weekly as we ramp up project progress.

The team also met with the teaching assistant staff and Professor Deliwala throughout the semester to better focus our problem and solution. We first met with Professor Deliwala in September to discuss the scope of the project and narrow down the project application. The team then met with Jason (TA) to discuss four different applications of the drone and which application best utilized a drone. After meeting with Jason and Professor Deliwala again, the team narrowed its focus on an assistant workout drone that would use limb detection to analyze skeletomuscular structure. We then consulted with Alfa (TA) in order to better understand her experience with limb detection and the advantages and disadvantages of different technologies. Finally, we met with Matt (TA) in December to discuss the projects problem solution statement in order to set the team up for success next semester. Each meeting provided the team with valuable feedback and allowed the team move through the design process and iterate through different ideas. The team now has a problem and solution that are interesting, important, and unique and the team is excited to move forward with the revised project next semester.

In addition to advisor and teaching staff meeting, the team met on every Sunday night for at least an hour in order to discuss the progress we made, needed to make, and important decisions in our pivoting process. We also met at least one more time during the week in order to work on any deliverables due for that week.

VIII. Reflection on Fall Milestone and Proposed Spring Schedule

8.1 Fall Milestones and Progress

From the very beginning of fall semester, we approached ideation, research, and development systematically. Our milestones demonstrate that entire process (Figure 2**)**.

At the beginning of September, we ran a "Darwinator" idea tournament for project ideas. The entire team anonymously submit ideas and then graded them on novelty, value, feasibility, etc. This allowed us to have a top-k list of ideas that we then discussed further to determine which ideas to go to faculty with. This was done by **September 15th**; and we had 10 ideas that we went over with prospective advisers (official or otherwise).

By **September 30th**, we had refined our list to the 4 most promising ideas. These were "Assistant Drone as Embodied Central Intelligence", "Extrapolative Continuous Recommendation Engine", "Flying Insect/Disease Vector Attraction and Elimination Device", and "Anti-deepfake Authentication Framework". For every idea, we had determined some critical tasks (go / no-go) that had to be accomplished for them to be possible. For example, the critical task for the recommendation engine was to implement a simulator that would simulate inherent preference and on-the-spot selection for an arbitrary number of consumers. While implementing that, we found that the core assumption on which the project rested was not as we thought: We would need much greater resources (at best) to isolate and extrapolate the utility/selection function of an individual. This was a core problem faced by everyone, even in the cutting edge of cognitive science research. Thus, having designed our entire process for such eventualities, we easily dropped that line of development.

By **October 20th**, all go/no-go tasks had to be completed, one way or the other. As it turned out, the successful one was the Assistant Drone; which was a tcp server that would send a list of commands to the drone, which would then fulfill them. Now that we knew with great confidence that this was the project to proceed with, we went back to our preferred adviser (which we had been in contact since the Sep 15th milestone); who then became our adviser in fact.

Professor Chaudhari recommended we determine a small number of applications (sub-problem/solutions) to demonstrate the value of a mobile assistant robot as a general solution to the relevant problems. By **November 4th** we had run another idea tournament for that specific purpose. We went through the same process, both for internal and external feedback, and ended up with 4 applications for the platform. One of these applications was "drone as a personal trainer"; which, after significant feedback, became our primary focus.

By **November 14th**, we had implemented a real-time drone driver with telemetry feedback.

By **November 18th**, we had implemented limb and joint angle detection via OpenPose. An example of this can be seen in Figure 3.

By **December 11th**, we had met with our advisor, the course faculty, and numerous TAs to get the team and the teaching staff on the same page. We needed to discuss course-specific requirements, our project's motivation, and our vision to explicitly establish the correct way to move forward.

As significant as our work may have been as far as the whole process is concerned, there is a lot of work to be done for our current project. While some of the work done for the drone-as-an-assistant project will certainly be useful for the physical trainer software, we have more than half the work of the project in front of us. To make up for this, some of our team will be spending a significant part of winter break (on and off campus) to work on the project.

8.2 Spring Milestones and Additional Requirements

Our milestones for the winter break and the spring semester are as follows (Figure 4**)**:

- Determine if limb detection accuracy and consistency is sufficient.
  - If not, train limb detection model using a Kinect
- Implement joint data extraction backend
- In parallel:
  - App interface
  - (Rolling-basis) Movement addition through medical research application. 3 to start with, but can be extended indefinitely.
  - Business plan

We plan these to be completed by **mid-February** if 3d model training is not necessary; since that seems to be the most significant time investment remaining. If Kinect training is not necessary, we have all the hardware we need for the remainder of the project. The mobile app will likely use React and NodeJS, but the specific stack we will use is going to depend on what the team can most realistically implement given our need to integrate the limb detection model. The schematic of the software process can be seen in Figure 5.

IX. Discussion of Teamwork

For a majority of this semester, the team was working on a proposed solution that included a drone, drone driver software, and a computer vision model. Hal's previous computer science coursework was essential in developing the interface of the drone. Chloe and Abe's knowledge from a Foundational Data Science course better equipped the team to tackle the limb detection software needed to analyze an individual's skeletomuscular structure. Ajmain's prior research in the GRASP Lab provided the team with the foundation to implement different computer vision techniques. While each member of the team brought a unique background that would aid in developing the proposed solution, the team still needs to collect information on proper form and technique used in workouts specifically angles to be used and which positions activitate which muscles. The team will need to use and analyze large data sets next semester in order to provide accurate and safe feedback to users.

The team divided the project tasks into two groups - software and hardware - to better divide tasks and utilize each individuals knowledge and skills to their fullest extent. While the team did split the work, the team met weekly to discuss the improvement made on each side as well as explain to the other team members how this was technically done and in doing so, all team members have gained an understanding of a topic they otherwise would not know about.

Due to his previous experience with the tello drone, Hal spent the first half of the semester working solely on the drone. He was able to implement a one way interface for the drone to receive commands via wifi and later on he was able to add to this and he implemented a two way interface that had location mapping functionality. Now that we have decided not to utilize the drone, we will reorganize the division of tasks next semester so that two team members will work on the limb detection software and two individuals will work on the smartphone application that will record a user and provide feedback. While Hal was working on developing the drone interface, Chloe, Abe, and Ajmain were researching computer vision algorithms with limb detection capabilities. They determined that OpenPose would be sufficient for the initial prototype although OpenPose had a lag. However, moving forward, the team plans to switch to a phone camera in order to make the product accessible to a larger market and to allow the interface to be easily used by a user.

The largest challenge faced by the team was defining a problem solution statement that was interesting, useful, and made sense. We started with an activity recognition drone, which was a solution, but not for a specific problem. We then moved to an assistant workout drone, which attempted to solve the problem of workout related injuries from improper form, but the solution using a drone was not the best solution for this problem. After several meetings, the team now understands that a phone will serve as the best solution to the problem we are interested in tackling. Next semester, the team will be working in overdrive to make up for lost time. The team plans to start next semester by testing the phone camera and developing a code that will provide skeletomuscular coordinate and joint angle information. We will utilize this information and collected data on proper skeletal coordinates to provide feedback to users through a smartphone application, which we will be simultaneously working on.

X. Budget and Justification

Our original budget was $0, and it will remain $0 for the foreseeable future. Originally we were utilizing the DJI Tello drone as part of our original solution, but we did not need to purchase it, as Halil already had one and offered for it to be used in the project. Aside from the drone, there are no costs associated with programming the software or utilizing the phone camera that is used in our current solution, since we all have access to a phone with a camera.

This budget, of course, is subject to change if we decide to test our solution against a 3D camera, like the one used by the Microsoft Kinect, or if we decide to enhance our solution through the use of wearable technology, like a smartwatch. For now, however, our budget remains the same, $0.

XI. Discussion and Conclusion

Throughout the semester we continuously refined our problem statement and our proposed solution. We began with an idea for an all-purpose drone personal assistant, which we then modified to an idea for a drone personal trainer, and has now become a personal training phone application. Although this means that much of our technical progress, specifically the progress concerning the drone, is no longer useful, we are not starting from scratch. We have already implemented limb recognition via OpenPose through a webcam, and have made significant progress in our joint angle detection software. Overall, this whole semester has been a learning experience for us about the design process as a whole, and we now have a much clearer vision for what our product will look like, and what steps we must take to get there in the next semester.

During winter break and next semester we will be focusing on testing our solution to ensure it functions properly and further fleshing-out our joint detection model. This includes validating our OpenPose joint detection model, and potentially testing it against a 3D camera. In parallel, we aim to develop our mobile app interface. We want this product to be simple and easily used by everyday people, so we aim to make the interface as intuitive as possible. Additionally, we plan to conduct research into proper exercise technique and incorporate that into our model, so that our app can properly give feedback to users about how to correct their form for optimal results.

The biggest challenge we foresee is the sheer amount of work that we still have left to complete in order to reach our final product. This is due to the nature of the design process, and the fact that we have removed the drone from the project, which accounted for a lot of the technical progress we made this semester. In order to tackle this challenge, we will be continuing to work on part of the project during winter break and setting clear deadlines for ourselves to reach milestones during the spring semester. If we hold ourselves accountable and divide the work properly, we should be able to properly tackle this challenge.

Additionally, we foresee that their may be a challenge in integrating the separate components of our solution into one final product. While we may have functioning limb detection on OpenPose running on a laptop, we do not yet have it running on a phone app, and there may be issues associated with that integration that we have not yet encountered. For that reason, it is in everyone’s interest to stay on schedule and work as much as possible during winter break, so that we can address these issues with time.

As mentioned previously, this semester has been challenging, but it has been a learning experience for all of us. The most important thing we have all learned is to listen carefully to feedback and address it properly. It is something that we have really taken to heart, as we have met with continuously with TAs, Professor Deliwala, and our advisor in order to ensure that we are on the right track with our product. While our project has had many adjustments since we first began, we have learned that iterations and modifications are all part of the design process, and we have learned a lot from it. We are looking forward to bringing Vitruvian to reality in the next semester, and we will continue incorporating feedback from both instructors and peers along the way.

XII. Appendices

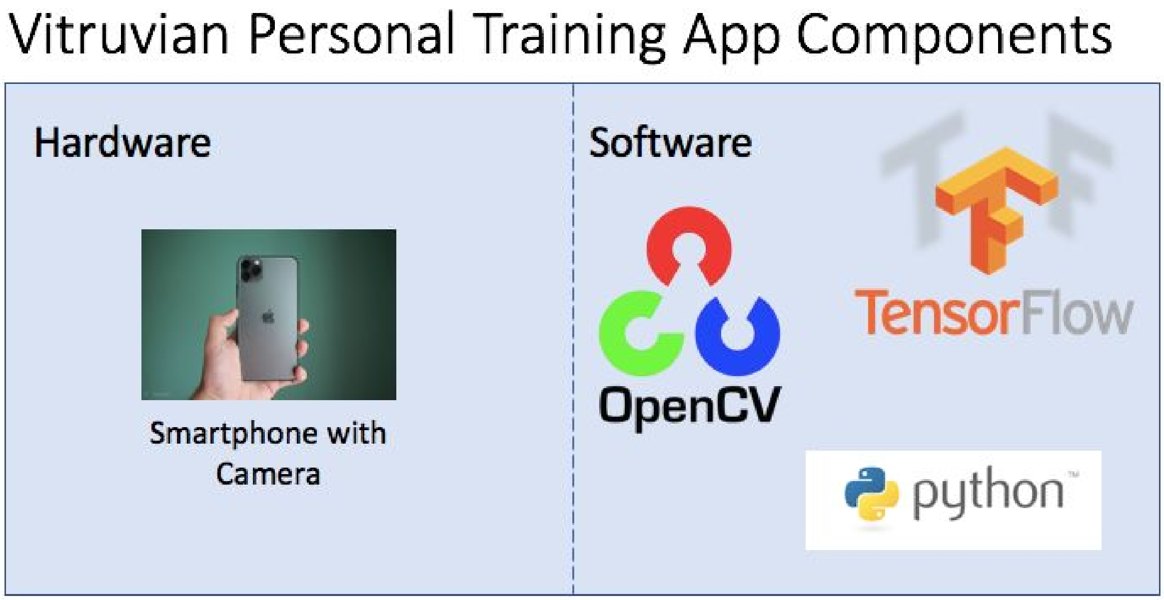

Figure 1. Components of our design

This diagram shows the split of hardware and software that we have incorporated into our design. The software we use includes OpenCV and Tensorflow running on python for limb detection, as well as python for the data processing and analytics. We kept the hardware simple and widely available. All the hardware that this solution requires is a smartphone with a camera.

Fall Semester Milestones

Task	Chloe	Ajmain	Abraham	Halil
Research "Tastebud" Machine Learning Requirements	9/30	9/30	9/30	9/30
~~Implement "Tastebud" simulator~~		~~10/20~~		~~10/20~~
Implement 1-way interface for drone to receive commands via wifi				10/20
Research potential personal assistant drone applications to narrow scope of project	11/4		11/4	11/4
Implement drone 2-way interface and location mapping functionality				11/14
Research and implement limb recognition on webcam via OpenPose	11/18	11/18	11/18	
~~Integrate limb recognition with drone camera and 2-way interface~~	~~12/2~~	~~12/2~~	~~12/2~~	~~12/2~~

Figure 2. Fall Milestones Table
Description of our milestones for the fall. Many of these milestones include much of the progress we made for the previous iteration of our solution, the drone personal trainer. Fortunately, the core of our OpenPose limb detection software will remain useful.

Figure 3. OpenPose Example
This is an example of what OpenPose limb detection looks like. It is clear, that it can accurately detect the limbs of people while they exercise, and that is why we have chosen to use it in our design.

Spring Semester Milestones

Task	Chloe	Ajmain	Abraham	Halil
Develop Phone Application with intuitive user interface	January – February			
Establish understanding of optimal workout practices				
Validate and implement data analysis/response from limb recognition				
Fully integrate OpenPose into phone application	March - May			
Test prototype/refine if any bugs appear				

Figure 4. Spring Milestones Table
Description of our milestones for the spring. We aim to work on the phone application in parallel with the validation and implementation of data analysis with the limb recognition in January and February. Then we aim to integrate and test everything in the remainder of the semester

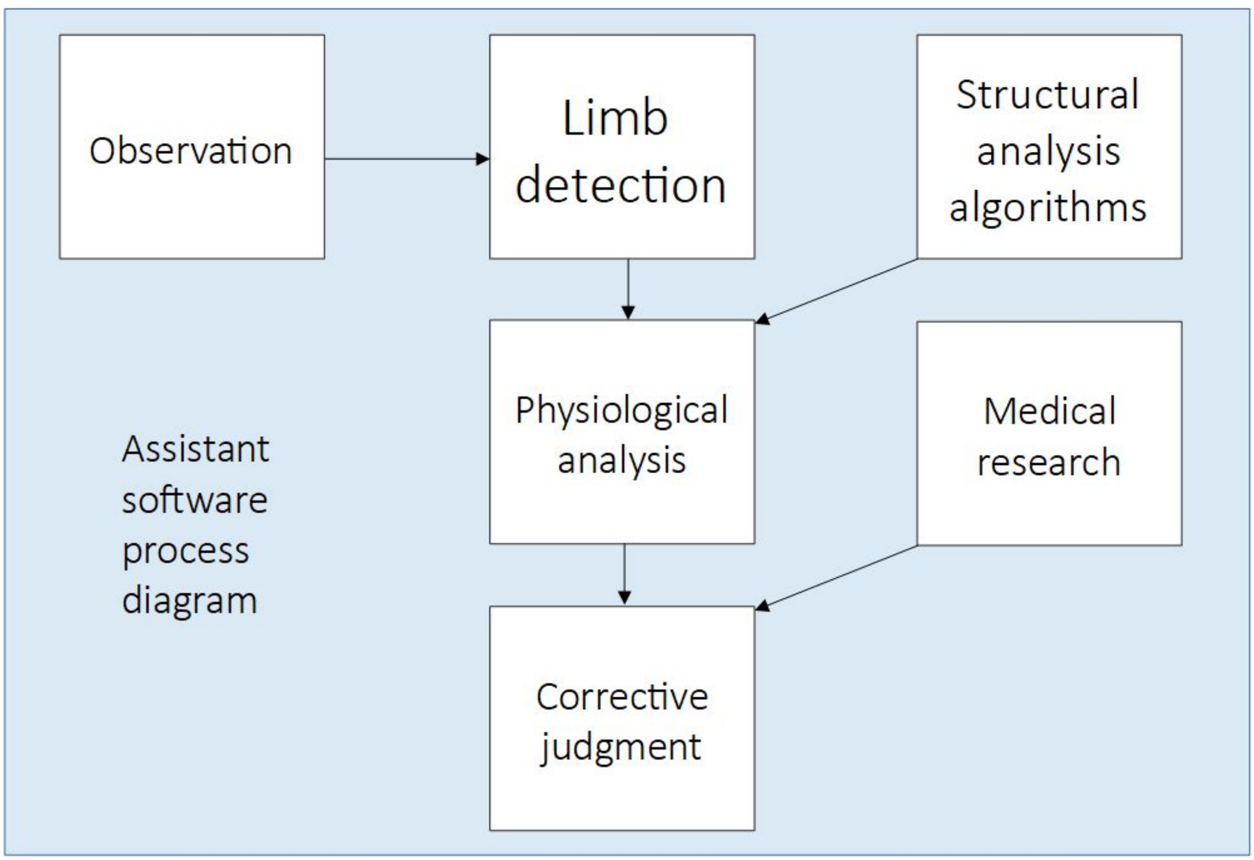

Figure 5. Software Process Diagram
This Assistant Software Process diagram describes the process in which the Vitruvian Personal Training App would work. First, the user's exercise motions would be observed by the camera,

then the user’s limbs would be detected and skeletomuscular positioning would be calculated through OpenPose, in combination with our analysis software. The user would then receive corrective judgement from the