Group 16 - Pose Capture

18-748 Wireless Sensor Networks, Spring 2018

Christopher Hung (christoh@andrew.cmu.edu)

Rini Mukund Patel (rinip@andrew.cmu.edu)

Tushar Goyal (tgoyal1@andrew.cmu.edu)

Project Mentor : Alex He

Website link : https://rinipatel.github.io/PoseCapture/

1. Project Summary

For our project, we plan to implement a system that will track a user's movements as they move their limbs. This system will use a network of nodes each with an IMU that will collect the data and relay it back to a master on a PC, which will collect the data and track the motion of each individual node.

2. Project Motivation

The recording of human position and pose has various application in the film industry, gaming, virtual reality, robotics and possibly medical training such as physical therapy etc. Many of these techniques are based on either computer vision based approach or sensor frame-based approach, where wired sensors attached to a frame are attached on a body of a person and data collected from them is used to estimate the pose. [1]

However, such techniques are not very ideal for human pose capturing as environment changes. In case of computer vision based techniques, they call upon the strong requirement for a person to be visible in front of capture device. For example, in case of robotics, a robot mimicking the actions of a human operator, the robot would either need to face the operator or have to be fed with the video feed of the operator via a camera present on the setup. Also, the illumination conditions and obstacles prevent the accuracy of these methods. Hence, the setup is not very portable for generic application, rather is limited to the space and use cases. Instead, having multiple small sensors that can be attached to various parts of the body that can capture the pose makes much more sense.

Similarly, there are sensor frame-based systems which can be used by humans to get the pose estimation. However, mechanical frames are constrained in form of portability and flexibility of movements. Additionally, the frame skeleton would need to be some lightweight strong material else the weight of frame itself can exceed the human weight and deemed to be unusable under certain medical conditions. A good frame with high flexibility of movements and lightweight material like carbon fiber can increase the cost of the frame and hence, the application in which they are being used. Lastly, these frames have to be made for various body physique and age groups, which itself is a very arduous task and seems applicable only for some specific scenarios.

One interesting methodology to capture the pose in literature was using acoustic methods. It uses the markers emitting signal attached to the body and set of receivers in the environment receive the signals and try to estimate the pose. The technique suffers from the interference from the environment and also suffers from the same problem as computer vision based methods where the person needs to be around and lack a way for receivers to be portable.

We want to take a wireless approach with inertial measurement sensors where the sensors could be attached to the body and the receiver software running on the host would use the inertial data to estimate the pose of the subject. The term inertial sensor comes from the group of sensors consisting of 3-axis accelerometer and gyroscope coupled with a magnetometer. The methodology doesn't suffer from portability and cost concerns since the sensors are relatively cheap and can be reused for multiple physique and age groups and have no constraints of weight and frame design for body movement etc. Additionally, unlike the cases of optical capture techniques where the video feed should be directly pointing at the human subject, the only constraint on the methodology would be the wireless network range to which sensors can send the data to the master where the pose can be estimated and there is no requirement of in direct line of sight. [1], [2]

3. Project Goals

The goal for the project is to get a full body capture of wireframe diagram for the human subject which can be used in multiple forms via some post-processing. The post processing uses the input from previous pipeline and gets a pose. Now, the post-processing stage would differ according to the application being used. For example, in case of film making, the pose capture might be used for VFX and animation where human like animations are created in animation.

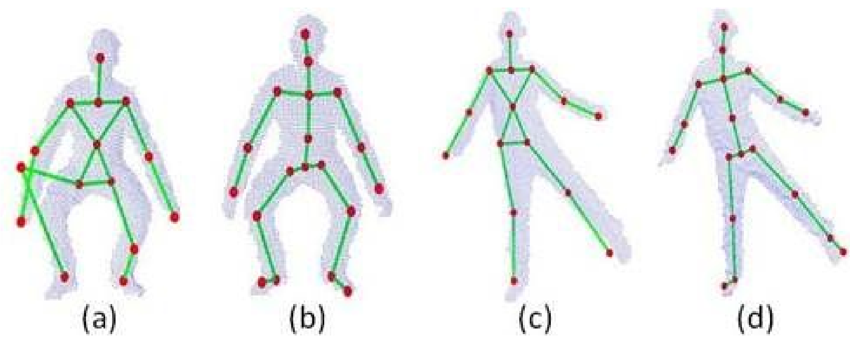

Figure 1. Examples of estimation results using pose tracking [3]

4. Key Use Cases

One use case would be in computer animation. Rather than manually move the limbs and body of a character, the animator can build a model of the character, act out the desired motion physically, and apply the recorded motions directly to the limbs of the model.

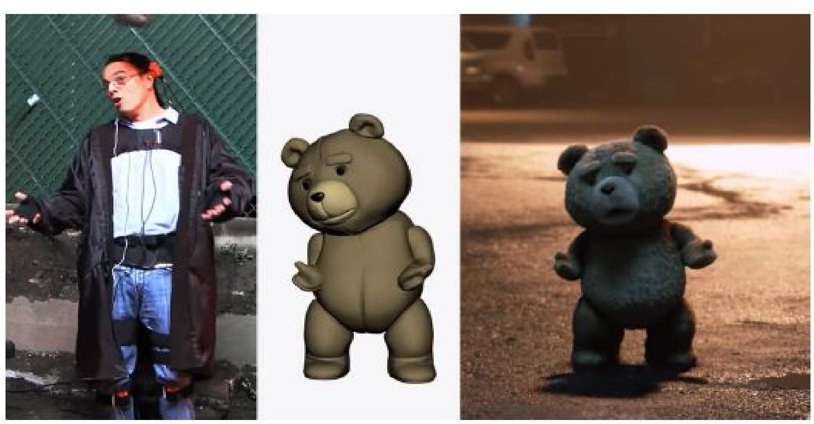

Figure 2. Actor Seth MacFarlane wearing 17 IMUs to capture his motion and animate the bear Ted [2]

Another use case is in virtual reality. With an accurate and low-latency solution, pose capturing can add another degree of immersion into the virtual world, where the user's motions are mirrored perfectly by the user's avatar. In case of robotics, the pose might be used to mimic the human behavior and hence, the pose estimated would be used to move the robot into a pose. This can be used to cases like where strong hydraulic robots could be used to move heavy weight objects around and human operator can just use the behavior to control the robot.

The most compelling use case for our methodology would be the cases when we require mobility, flexibility and line of sight requirement is not necessary. For example, consider the case when a pose capture application is required in medical scenarios where various age groups and physique need to be considered, the wireless IMU technique has significant advantages over frames.

5. Methodology - What is your proposed solution? How will you tackle this problem?

To implement our solution, we will build a network of several sensor nodes that communicate to a master. The data collected from these nodes will allow the master to track the movements of each node, allowing the master to get the relative positioning and orientation of each of the nodes. With the nodes situated on key parts of the user's body, the orientation and position of each node will give enough information for the master to estimate a pose.

6. System Design – perhaps block diagrams, subsystems and components

Key hardware components for our project:

- Arduino Uno boards + WiFi shields
- IMU Sensors

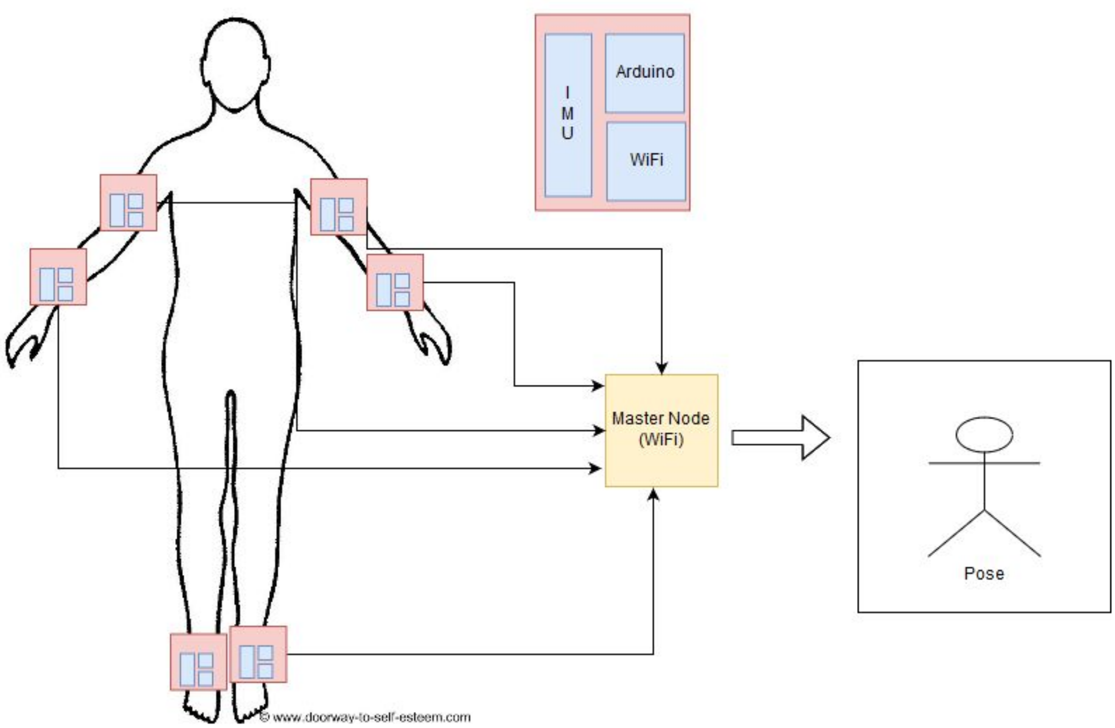

Figure 3. Arduino and IMU attached to body being used to estimate position by aggregation of sensor samples at master node

IMU sensor nodes will be mounted on Arduinos. Each Arduino board will collect rotation and acceleration data from IMU sensor, and send it wirelessly using ESP WiFi modules to the master node, which is an Arduino board attached to PC. Master node having received data from all sensor nodes, will offset it with the initial calibrated values of pose and try to estimate the new pose. The main focus is on developing system with low latency and getting more real-time estimation of movements. The master node will have fixed sampling time for receiving the new pose data, and after that it will update the visual representation of pose in form of stick figures.

7. Demonstration Sequence

- Intermediate Demo
    - Set up wireless communication between sensors, and track the motion of each sensor.
    - Demonstrate a full body pose capture ability with sensor nodes.
- Final Demo
    - Start with multiple sensor nodes mounted to different parts of body. As a person walks around or changes his pose, the pose can be seen on the GUI on PC/Laptop.

8. Development Milestones

- Wireless communication
    - Communication between arduino and external wifi board
    - Connection between board and master
- Motion tracking
    - Read data off the IMUs
    - Use data from IMUs to track motion of individual nodes / get orientation
- Pose capture
    - Build model of human limbs
    - Map position and orientation of nodes attached to limbs to a configuration of the limbs

9. Work Partitioning - How will you partition work among team-members?

We plan to start working together to assemble the hardware i.e. IMU, Arduino and WiFi board for it. After that the work can be subdivided into three parts. First part is to setup infrastructure for wireless communication from Arduino nodes to the Laptop or Arduino Node connected to PC. Second and third parts of the work is to clock synchronization amongst Arduinos and read data from IMU sensors at high rate. Hence, initial work can be partitioned by each team member picking up one part of the work.

Once basic system is setup, the full body model would be needed to be incorporated at the aggregation point for estimating the pose for full featured pose estimation. We think that two people can work on figuring out to provide data input in necessary format and trying to make the full body model work. The third person can work on developing a prototype of graphical user interface on basis of some test data instead of having real time input which can be later on replaced with real time pose perception captured from IMU.

During the full length of the project, all group members plan to try to do literature review and discuss understanding so that everybody is on the same page.

10. References

[1] Y. Zheng, K.-C. Chan, and C. C. L. Wang, “Pedalvatar: An IMU-based real-time body motion capture system using foot rooted kinematic model,” in *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2014.

[2] M. Kok, J. D. Hol, and T. B. Schön, “Using Inertial Sensors for Position and Orientation Estimation,” *Found. Signal. Process. Commun. Netw.*, vol. 11, no. 1–2, pp. 1–153, 2017.

[3] M. Ye, X. Wang, R. Yang, L. Ren, and M. Pollefeys, “Accurate 3D pose estimation from a single depth image,” in *2011 International Conference on Computer Vision*, 2011.