Motion Tracking for Smart Home Care

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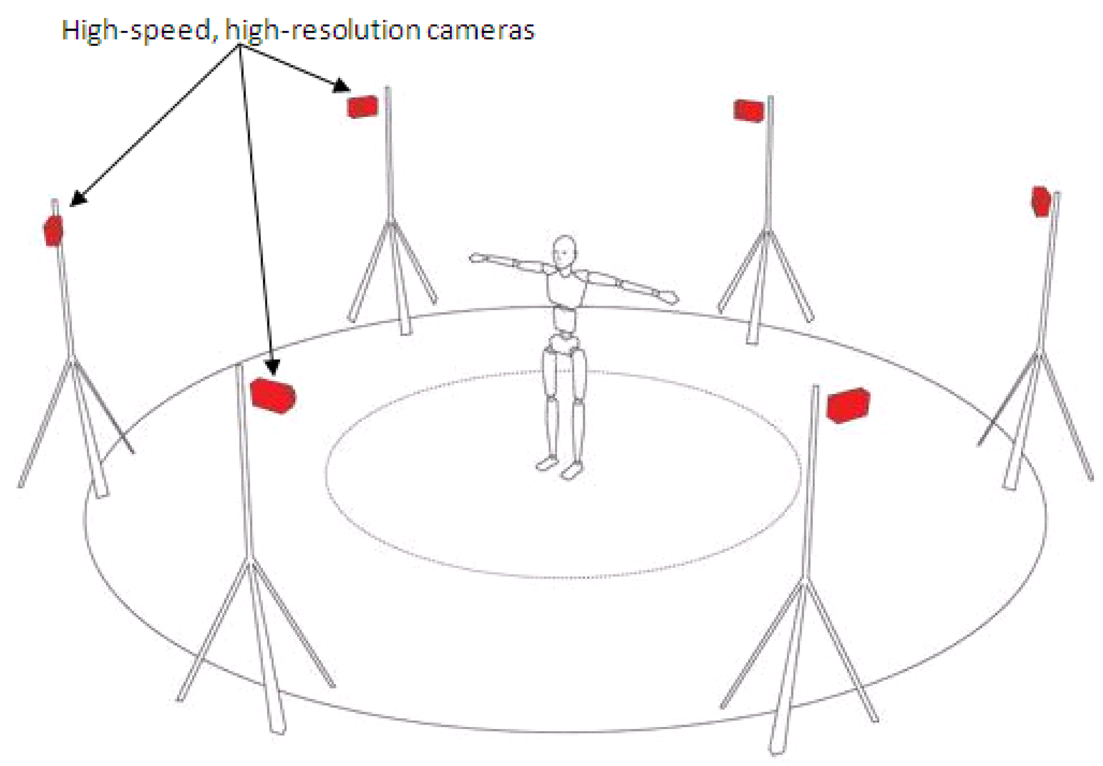
Abstract: Human body motion capture has a wide range of applications and is being extensively investigated. Areas of application include virtual and augmented reality, biomechanics, sign language translation, gait analysis and graphics in movies and video games. The goal of this work is to develop an electronic device to translate arms motion and hand gestures into computer commands for smart home applications. This device is expected to improve the communication and lifestyle of elderly and disable people. We envision a device that is wearable, seamless and easy to use. Current state-of-the-art body motion capture employs high-speed and high-resolution cameras. Although this method is accurate and useful in laboratory settings, it requires the user to be inside the field of view of the cameras, a condition that is not always feasible during everyday activities. Instead, our approach relies on small sensors nodes that are worn on the wrists and around the waist. Inertial sensors such as accelerometers and gyroscopes have been employed before to develop wearable motion-tracking sensors due to their small size. However, they suffer from drift which causes the position estimations to have large errors. Ultrasonic sensors have also been employed to track motion. Although more accurate, ultrasonic sensors are affected by intermittent signal blockage produced by the body. Our approach is to combine these two sensing modalities in a way that the position estimation error is reduced. To that end, the outputs of the inertial and ultrasonic sensors are fused using a Kalman filter. The sensor nodes implement a multilateration algorithm that calculates the position of body-mounted sensors by measuring the time of travel of ultrasound bursts traveling between the sensor nodes. An electronic board for the sensor nodes have been designed, fabricated and programmed. The board measures 3.2 cm x 4.8 cm and includes a low-power microcontroller, a radio unit, a three-axis accelerometer, a two-axis gyroscope, an ultrasonic transmitter and an ultrasonic receiver.

Our ongoing activities include the development of a 3D virtual *simulation* of a smart home. In the virtual smart home, various electronic devices such as computers, cell phones and household appliances like microwaves and televisions are networked for ubiquitous services. The wearable sensors capture the limb movements and relay this data to a central controller where it is interpreted to adjust the home environment. The sensors can also be used for emergency care by detecting any *abnormal movements*. Our approach will significantly improve current motion capture systems that are too cumbersome to wear or require the subject to be confined to a controlled environment or within the view range of the camera. Besides their use in smart home scenarios, the proposed wearable motion-tracking sensors can be used in biomechanic studies, virtual reality and interactive games.

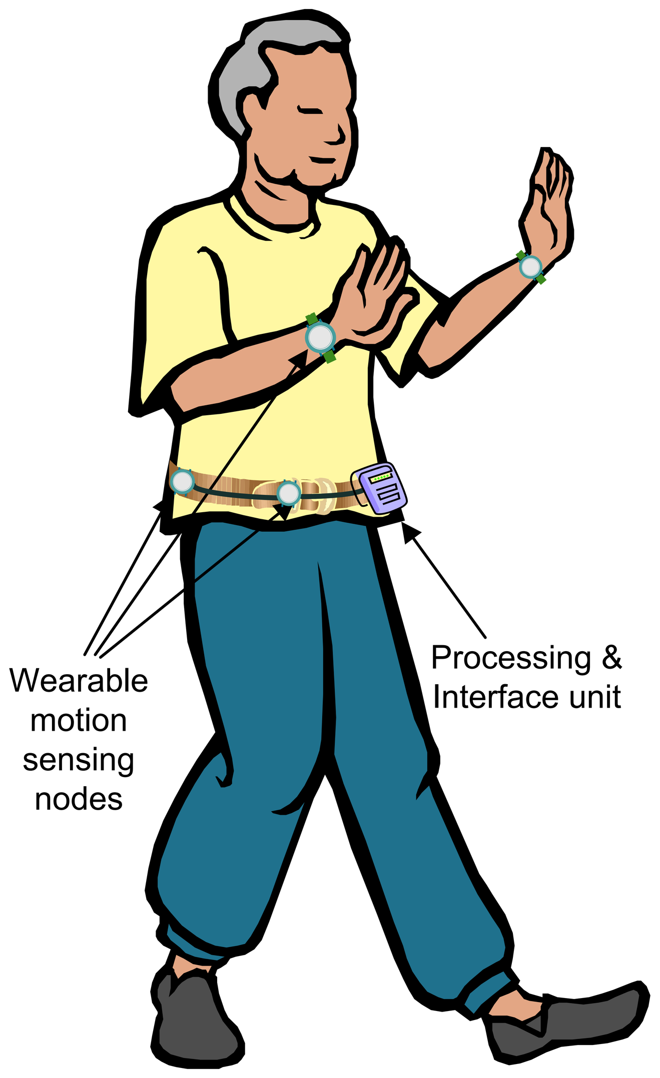
Motivation

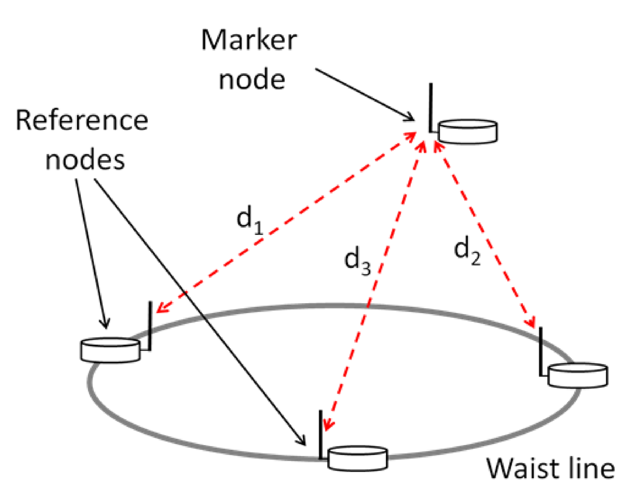
The motivation for this work came from the need for making motion capturing independent of being inside the field of view of high-speed and high-resolution cameras. We envision a device that is wearable, seamless and easy to use that could improve the communication and lifestyle of elderly and disable people.

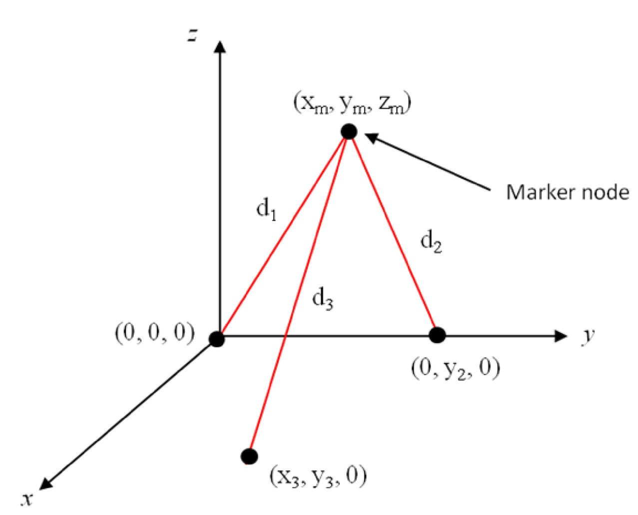
Current Used Methods



Proposed Solution





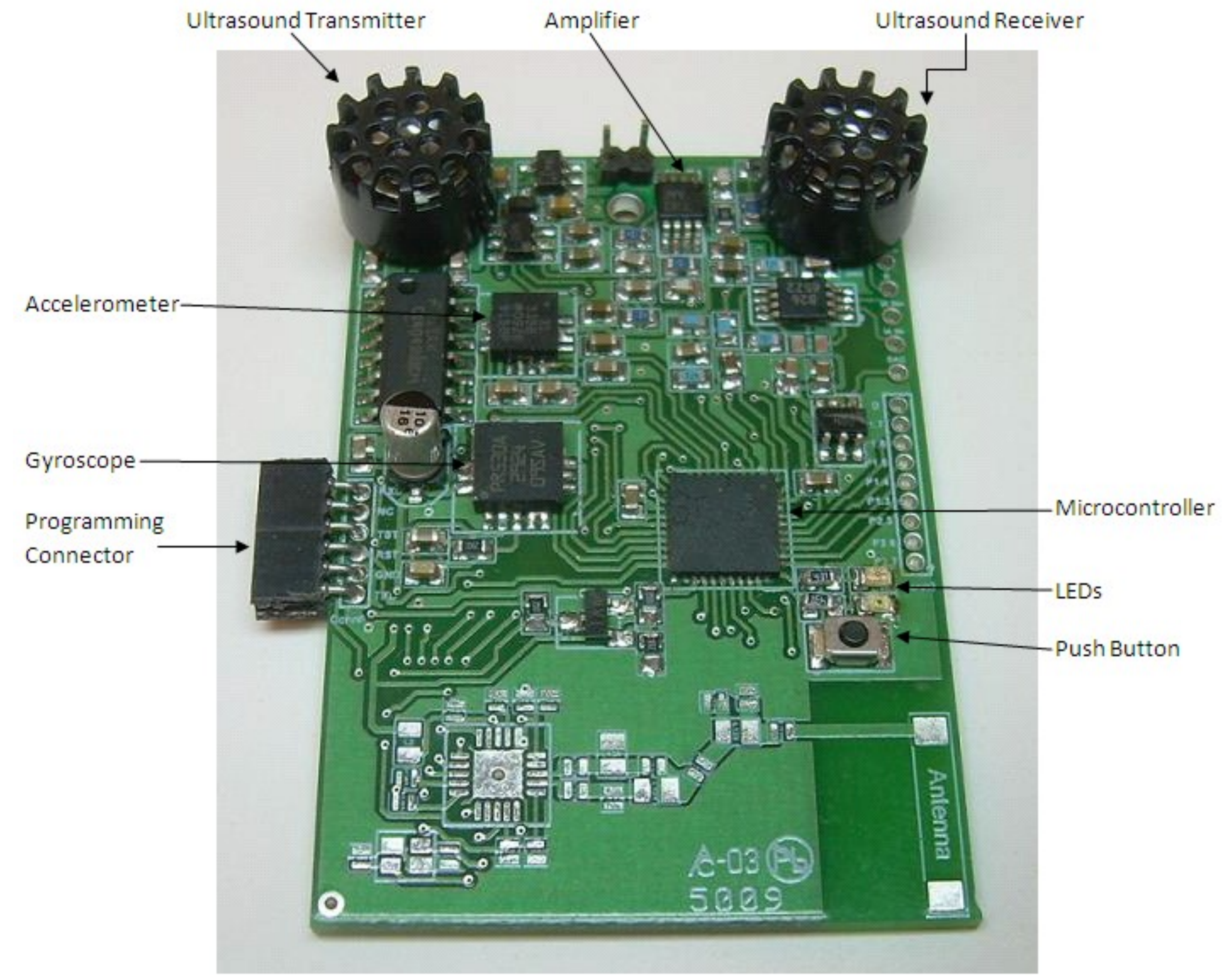


$$x_m = \frac{d_1^2 - d_3^2}{2x_3} - \left(\frac{d_1^2 - d_2^2}{2y_2}\right)\frac{y_3}{x_3} + \frac{x_3^2 + y_3^2}{2x_3}$$

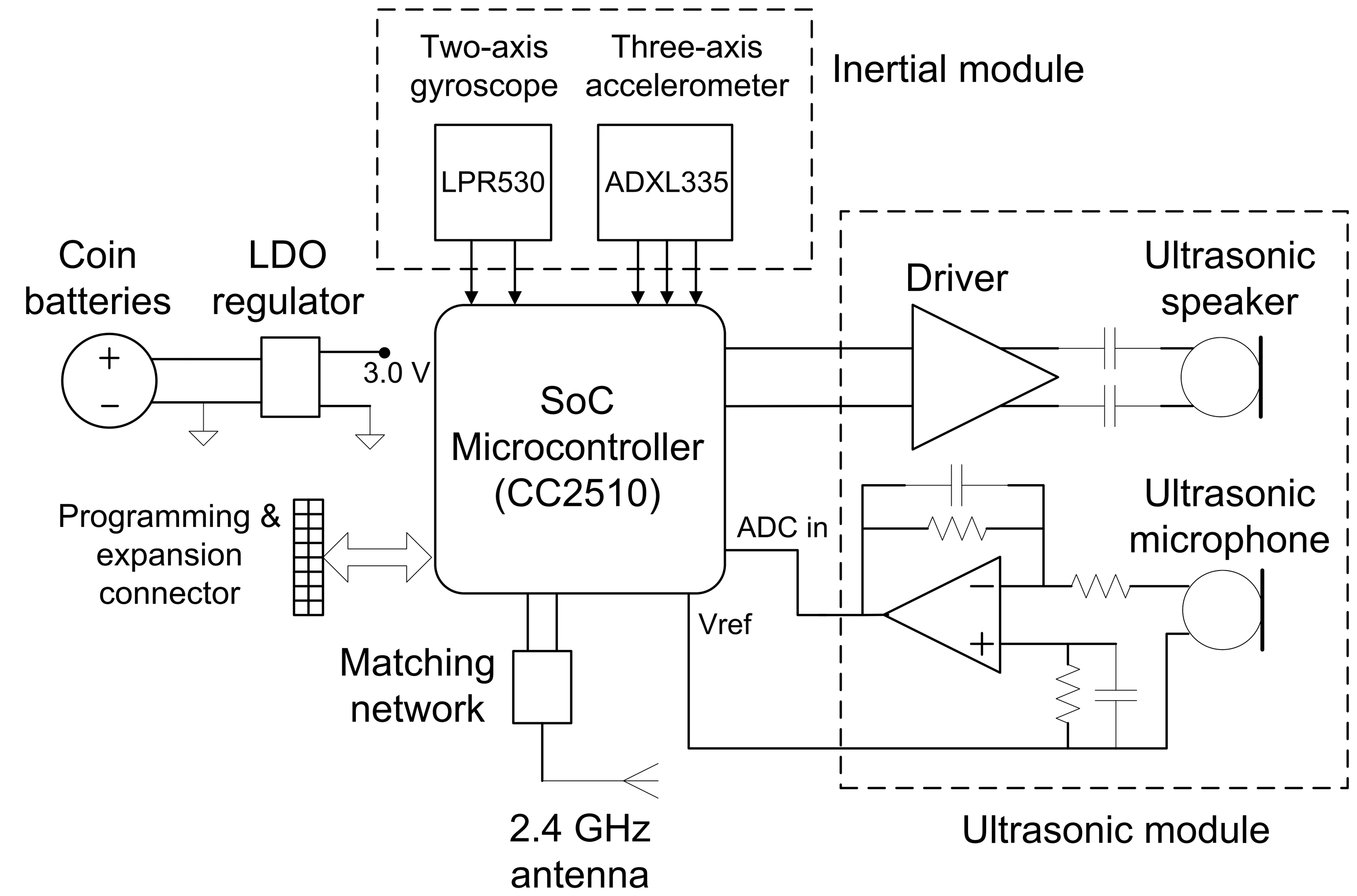
$$y_m = \frac{d_1^2 - d_2^2 + y_2^2}{2y_2}$$

$$z_m = \sqrt{d_1^2 - x_m^2 - y_m^2}$$

Motion Tracking Unit Board



Circuit Design



The ultrasonic emitters periodically transmit pulses that are received by the reference sensors. Upon reception, the reference sensors record the time of arrival of each pulse and use this time information to compute the range or distance between the reference and the moving sensors. A multilateration algorithm uses the range information to calculate the position of the emitting sensor. This technique has been used in the past to track people and cameras inside buildings and it has resulted in position measurements with sub-centimeter accuracies. Although accurate, this technique suffers from temporary occlusions of the ultrasonic signal, geometric dilution, multipath propagation, wind and temperature changes. In these cases, ultrasound ranging does not yield reliable position estimates. To address this problem, the investigators are proposing to employ inertial sensors as a redundant source of position information. The position estimates from the ultrasonic and inertial sensors are fused or blended together to obtain accurate and reliable position estimation.

Conclusions and Future Work

- A wearable motion sensor to capture human body motion has been presented.
- It will be used to translate arms motion and hand gestures into computer commands for smart home applications.
- This device is expected to improve the communication and lifestyle of elderly and disable people.
- Four node boards have been designed and fabricated.
- The work to be performed includes testing the transmission and reception of ultrasound pulses, assessing the accuracy of the outlined ranging method, and implementing the multilateration algorithm.