MPSYS TECHNICAL MINI FAIR

Master programme: System, Control and Mechatronics

Knee angle measurement

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Abstract

The field of movement analysis is a important tool for many medical decisions as well as its usage in rehabilitation. The main technology used today is big and bound to one location. To both allow for more data during a longer period of time at their own home. This can release resources at the hospitals.
There has been research done into the field with varying approaches. The focus in this approach is the usage of IMUs for measuring the knees angle. With the usage of accelerometers the angle can be easily calculated but where to place the sensors can be problematic. Multiple approaches has been promoted, some with the usage of multiple IMUs, some with a automatic calibration and others with the distance assumed.
The knee can be simplified to a hinge to ease the calculations. This project chose to incorporate a DCMR solution with virtual accelerometers combined with a rigid solution to calculate the angle. With a low pass filter the accuracy is very good and can follow the true angle in fast movements . The solution eases the use of the device and gives a safety in calculations. The rigid system is a good platform to add more features such as a modular resistance in the future.

Background

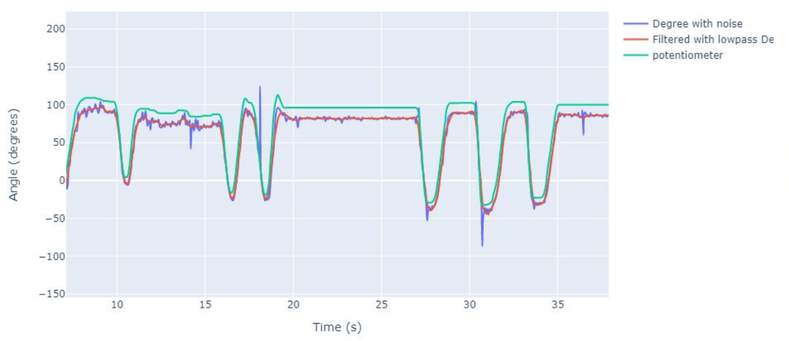
Movement analysis is a important part in alot of fields in medicine, especially rehabilitation.
The most widely used technology for angle measurements today are big and bound to a location. Rehabilitation is a constant undertaking and therefore being able to track progress at home with a easy to use device is essential.

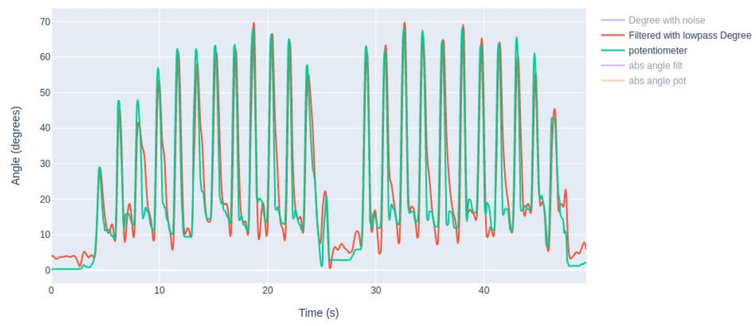
Result

- A constant error of at least 5° is consistent between all tests.
- The sitting test had the lowest RMSE.
- In the quick angle change test, an angle overshoot of 2° during 0.2 seconds was estimated.
- Significant false angle changes might occur.
- Sometimes there is sudden spikes in the calculated angles.
- The Accelorometers shows a good result compared to the benchmark.
- The filter is very successful in removing big errors.

This can be seen on the graphs to the right.

Test	RMSE	Sampling time [ms]	Freq
Stationary 45	6.58	8.58	116.5
Stationary 90	3.96	8.58	116.5
Sitting	5.14	16.6	62.5
Walking	7.07	16.6	62.5
Quick change	13.5	17.4	57.5





Method and discussion

Sensor placement

- Physical sensors need to be perfectly placed on joint.
- Usage of 2 IMUs on each side to create a Virtual IMU on the joint

Filtering

- Large component from the gravity. Used as reference.
- Higher frequency disturbances removed with low-pass filter

Angle Calculations

- The sensors on each side represent a virtual IMU on the joint
- A simple tangens

Modeling of the knee

- Hinge model of knee to simplify calculations
- The hinge simplification of the knee misses finer details that are interesting in some areas of rehab

IMU challenges

- Physical sensors need to be perfectly placed on joint.
- Usage of 2 IMUs on each side to create a Virtual IMU on the joint

Rigid solution

- Gives a failsafe and guaranteed distance to the joint. Easy mounting
- Can be used as a base for a resistance to increase use cases
- Can be clunky

Conclusion

The solution requires no measurements or precise positioning to be done when mounting allowing a patient and/or user to attach the construction themself with the data processed and analysed remotely. The measured angle is accurate enough to determine motion patterns and approximate angles, however better sensors should be used to increase the absolute accuracy.We believe the achievements made in this work proves the usefulness and potential of using accelerometers to measure the mobility of a hinged joint in a rehabilitative environment.