

Movement Intention Prediction to Find a New Exoskeleton Design with Light and Comfortable Materials

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Abstract. This paper presents a discussion about the design a novel exoskeleton and the implementation of superficial magnetic sensor and pressure sensor for find patterns and parameters in order to predicting the intention of movement for people with musculoskeletal system problem in lower limbs. The information is obtained through reading position and movement by magnetic and pressure sensor installed in different parts of the body. The advantage of this sensor is the location of the position reference of the every part of the body. Using the sensor in some parts of the body is possible to calculate the muscle contraction for the prediction of intended movement and to find a new design with light and comfortable materials.

1. Introduction

The developments of exoskeleton for people with musculoskeletal system problem in lower members are increased in the last years. The most relevant design issue is the interaction between user and the machine. Today, it is possible to find speech, joysticks or electromyography controlled system. [1] Miniature accelerometers became available which measure acceleration forces. This sensor can be used to monitor inclination of body part, but the sensor can no detect the horizontal component of the orientation. [2] Other way, the magnetic sensor can measure orientation relative to the magnetic reference. The sensors are located in the way to detect the horizontal component and vertical component for complete orientation monitoring.[3] Apply intention of this technology is to allow monitor the body limbs orientation, in order to assess the intention of the movement. Orientation estimation in human motion tracking systems needs various types of sensor. There are commonly used: accelerometers, gyroscopes and magnetometers. [4] Used individual sensor have varying advantages and problems. Gyroscopes measure angular velocities by integrate the data over the time allowing to find the orientation, but the integration of gyroscope measurement produce errors on calculated orientation. Accelerometers measure the linear acceleration and gravity.





Figure 1. Exoskeleton controlled by movement intention.

Magnetometers are used to measure the local magnetic field vector allowing to the determinate of orientation relative to the vertical axis. The problem with magnetometers is the influence of magnetic interferences to the sensor frame or ferromagnetic materials around the sensor (Fig 1). To avoid all of this problem is necessary the use of filtering algorithm.[5]

Regarding to a filter technology, there are frequently filter design: deterministic, frequency approach and stochastic. The deterministic filter is used to find a rotation matrix between two coordinate systems. It can be used to find a best orientation from different sensor measurements. Orientation estimation filters for human motion tracking, the magnetic measurements are determinate by the gravity field or the magnetic reference into the exoskeleton. [6]. The most common motion capture systems for body motion application are based on either optical or inertial/magnetic sensing.[7] Optical tracking is based on the captured images processing of by multiple cameras. Identifying body parts to track, the system has made a following of the anatomical parts of interest and their detection. Infrared cameras produce streams of coordinates representing the using a reference system, with application in medical contexts. The reason is the reliable and accurate necessary to record the motions. In the optical tracking measures the orientation of the body parts of interest. It made by means of cameras operating in the visible spectrum and without marker. This system is less expensive and more portable than marker based on optical systems. [8] The system designed is wearable and reliable human motion capture system, based on the use of magnetic and pressure sensors units that are attached to the lower limbs in order to track their orientations. The motion tracking systems uses low cost pressure and magnetic sensors.

The use of inertial sensors was mostly investigated for biomechanical applications, like gait analysis, joint angle and body position. There is no inherent latency in this sensing technology or delays. Additional, the system does not use external source, whereas electromagnetic, acoustic, and optic devices require emissions from a source to track objects. It does not expose to limitations and interference problems of other sourced technologies.

2. Method

Position sensors measure the distance a body has moved from its reference and the resulting output is given as a feedback to the control system in the exoskeleton. Motion of a body can be rectilinear or curvilinear, for this reason the position sensors must detect linear position or angular position. The

sensors have accuracy limitations, the outputs signal is mixed with noise. Therefore, the quality needed to provide an accurate estimation is not necessary to be high. The sensor outputs can be filtering with algorithms that provide the good estimate of possible orientation. The final design take in account a good filters design for real-time applications that because accurate and computationally demanding algorithms required and it will may be too slow to work in real time.

Kalman filter produces estimates of the state variables and uncertainties to predict the position all time. The algorithm can run in real time using input measurement and the previously calculated state. The Kalman filter used, works with nonlinear systems associated with the process model. It is well used for orientation estimation problems in human motion tracking applications. Finally, offset angles are calculated representing orientations that have to be applied in order to overlap the sensor frame to the body frame. These angles are used throughout the motion tracking process to align the measured orientations to the body segments.



Figure 2. Sensor Position.

Additional aspect in the accuracy of the orientation estimation depends on the quality of result data provided by sensors (Fig 2). Because these reason high-end sensors are used that require a compensation of their systematic errors by sensor calibration procedure. The magnetic behavior can be influenced by electromagnetic interferences and magnetic materials in the surrounding that distort the measurement. To avoid this error measurement, compensating parameters must be applied to every magnetic sensor use in every environment. Fuzzy logic use a position degrade with previous acknowledge of the data to determine the final result. The data measure is continuing variable that is processed to control the exoskeleton properly.

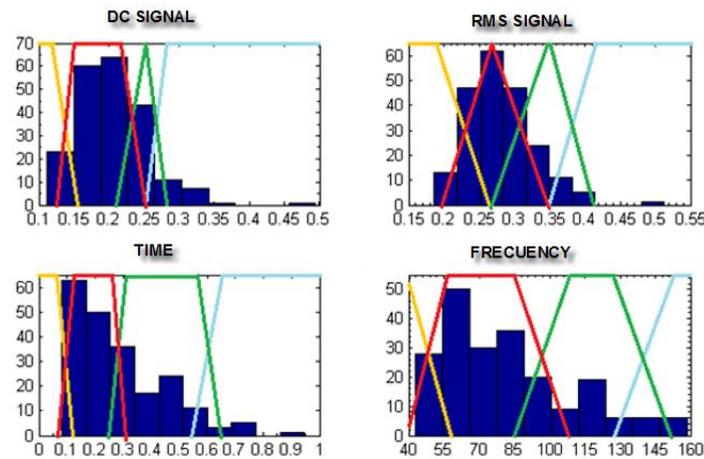


Figure 3. Histogram of the basic movement on stand up.

$$DC_{calculated} = \frac{\sum_{i=1}^N RMS(i)}{N} \quad (1)$$

$$RMS_{calculated} = \sqrt{\frac{\sum_{i=1}^N RMS(i)^2}{N}} \quad (2)$$

$$Time = t_{end} - t_{start} \quad (3)$$

To find the movement intention is necessary a data base to process (1),(2,3), compare and conclude based on de information, the movement. It is very similar to human decision. The human body need information missing a set of lose data to realize a movement. The human learn during the life specific movement, and this information is executing automatic. The same way, the fuzzy logic use a base data to decide how control an exoskeleton (Fig 3.). The fuzzy logic software use the information to transform in a diffuse group of data, related on some degrade with other group of data.

3. Conclusion

This method is accurate and applicable to detect intention of the movement. The present work aimed to use magnetic and pressure sensors to develop mechanics and electronics system for combined sensor, and use the fuzzy logic mathematic to control the exoskeleton with the movement intention of the user.

4. Discussion

The most common characteristics used because the low complexity and low computation time consumption, are the DC level RMS value, the signal time slot and the harmonic in frequency. The noise signal relations are obtained by means of filtering step.

This work represents an overview technologies used for human motion tracking with pressure and magnetic sensors and the fuzzy logic algorithm based on the result of the design of an exoskeleton for detect the motion intention for people with musculoskeletal tension. The result is used in the creation of an exoskeleton with intention motion control.[9] The methodology include motion intention estimation algorithm based on fuzzy logic for fast response on real time measurement and development of novel solutions for exoskeleton final design. The developed sensor and fuzzy logic mathematical processing do indeed monitor body position and prediction of the intention of the movement. [10] This seems sufficient for monitoring the intention of the movement for many applications. For other applications, control of the exoskeleton may have to be improved. The main Limitation is the sensor sensitive to movement accelerations and to fluctuations of the orientation of

the environmental magnetic field. When taking into account these limitations, the intention of the movement can be easily monitored. [11]

5. Results

The result is measurement data of the orientation of the lower limb and simultaneously with pressure sensor, installed in the muscles of the lower limb, in order to allow the detection of the intention of the movement.

A brief comparison between fuzzy sets of data is done to determine the best system in generating reliable control orders for prototype robotic exoskeleton. The fuzzy system designed has nine rules in the inference engine, which had two stages of interaction with samples: one design and other validation. Analog and digital components for data acquisition processes are used to perform amplification, filtering, digitization and transmission of samples to fuzzy logic system.

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7. References

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