42 Aero Camino, Goleta, CA 93117
Tel (805) 685-0066 | Fax (805) 685-0067
info@biopac.com | **www.biopac.com**

6.17.11b

Application Note 266 BioNomadix Tri-Axial Accelerometer Data Analysis

Overview

This application note illustrates some of the potential uses and data extraction possibilities associated with the BioNomadix Tri-axial Accelerometer (BN-ACCL3) from BIOPAC Systems, Inc.

It is possible to extract a wide range of meaningful information from tri-axial acceleration measurements. This application note considers an example case of measurements associated with a subject who is using a broom to sweep a room. Data associated with acceleration, velocity, position, applied forces and caloric expenditure are considered.

Hardware

The tri-axial accelerometer sensor internal to the BioNomadix wireless Accelerometer is a wide range, accurate and stable MicroElectricalMechanical System (MEMs) - based accelerometer. The BN-ACCL3 delivers data in units of "G", namely meters per second squared. The BN-ACCL3 is capable of measuring in the range of ±16G.

Analysis

Using signal-processing strategies, it's possible to extract both [velocity-of] and [distance-moved] measures associated with a mass subjected to measured accelerations. Mathematically, velocity is simply defined as the integral over time of acceleration and distance is defined as the integral over time of velocity.

Certain practical concerns are of significant importance when considering the integration of acceleration data. As example, if acceleration data has some initial baseline (zero acceleration) value which is non-zero, then this offset will be integrated into the resulting velocity measure.

Practically considered, baseline offsets and accumulated baseline associated errors are easy to remove via the use of band pass filtering.

The implications of band pass filtering are as follows:

1) All baseline (offsets and slow drift) of accelerometer are removed and high frequency (jitter) measurements are smoothed. Smoothing results in more easily interpreted acceleration data that is characteristic of the human motion range. Also, any constant offset resulting from gravity would be nullified after band pass filtering.
2) The resulting velocity data, after integrating band pass filtered acceleration data, will manifest as a well-characterized velocity measurement with tendency to return to a velocity baseline of 0 meters/sec for velocity measures which change at a cyclic rate at less then the band pass filter range.
3) The resulting distance data, after integrating band pass filtered velocity data, will manifest as a well-characterized distance measurement with tendency to return to a distance baseline of 0 meters for distance measures which change at a cyclic rate at less then the band pass filter range.

The key issue associated with band pass filtering is to isolate the movements of interest. In the case of sweeping the floor, evaluation indicates primary motion activity in the range of 0.5 Hz to 20 Hz. This means that the motion frequency range of interest will be between 0.5 cycles/sec to 20 cycles/sec.

Typically, the band pass filter range chosen relies on visual inspection of the activity of interest. In the case of sweeping the floor, the broom motions used by subjects is essentially oscillatory, as is the case with nearly all human activity, such as walking, running, jumping and throwing. When considering broom use, it was estimated that the slowest back and forth sweeping motion cycle was 2 seconds. The inverse of 2 seconds per cycle is 0.5 cycles/second or 0.5 Hz. At the high frequency side, the fastest sweeping cycle time was deemed not to exceed 50msec. The inverse of 50msec per cycle is 20 cycles/second.

Movement-related details (acceleration of, velocity of and distance moved), such regarding the motion of the subject, a particular portion of the subject's body or the broom, can be obtained by placing the BN-ACCL3 on the location of interest.

By using the BioNomadix acceleration data directly, it's possible to employ the formula (f=ma), or force (in Newtons) equals mass (in kg) times acceleration (in meters per second squared), to obtain an estimation of the forces involved when sweeping with the broom. One Newton equals 0.2248 pounds of force.

Also, by employing the formula e=½mvv, or energy (in Joules) equals ½ times mass (in kg) times velocity (in meters/sec) squared, it's possible to estimate the kinetic energy used to employ the broom. In addition, using this energy data, it's possible to perform an estimation of the additional caloric requirements needed by a person to use the broom over a period of time. More specifically, calculated average kinetic energy data would indicate the calories burned by the subject to maintain a specific activity level using the broom. One Joule equals approximately 0.239 Calories.

The following data graphs illustrate collected and signal-processed acceleration data taken from a subject's wrist while using a small hand-held broom. Acceleration data was measured in both the Y (side-to-side) and Z (up-down) axis.

Note that Acceleration data is largely constrained in the region of ± 7G for both the Y and Z axis.

- The most acceleration (movement) activity is evident in the Y axis, for this particular sweeping motion.

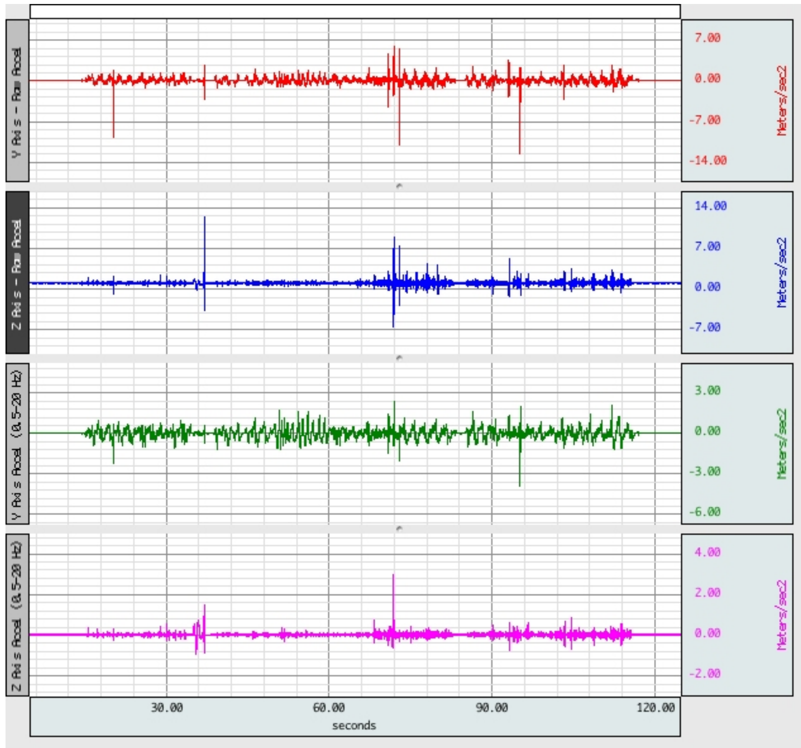

Figure 1: Y and Z Axis Raw and Band pass Filtered Acceleration

This data graph consists of velocity data which was obtained by integrating the band pass filtered Acceleration data in Figure 1.

Note that velocity data is constrained in the region of ± 0.25 meters/second for both the Y and Z axis.

- The most velocity (movement) activity is evident in the Y axis, for this particular sweeping motion.

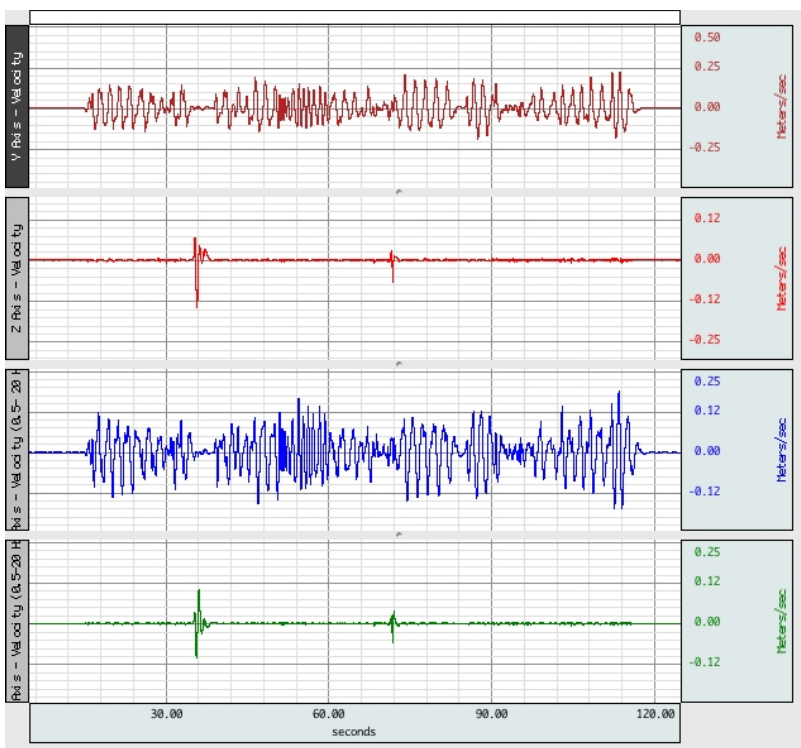

Figure 2: Y and Z Axis Velocity and Band pass Filtered Velocity

This data graph consists of distance data which was obtained by integrating the band pass filtered Velocity data in Figure 2.

Note that distance data is mostly constrained in the region of ± 0.06 meters (±6 cm) for both the Y and Z axis.

- The most distance (movement) activity is evident in the Y axis, for this particular sweeping motion.

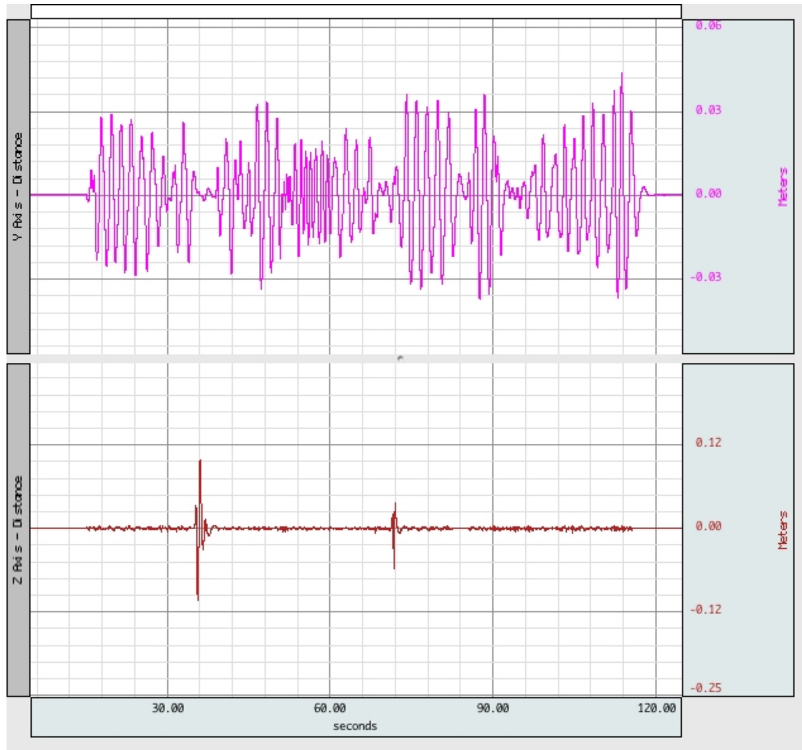

Figure 3: Y and Z Axis Distance

This graph examines the Y axis acceleration data an employs it to calculate the related forces involved along that movement axis.

The formula f=ma is used, with the assumption that the lightweight broom weighs 1 kg.

- Top waveform is measured acceleration.
- Middle waveform is force calculated (f=ma) and converted to an absolute value measure.
- Bottom waveform indicates the average (side-to-side) absolute force used by the subject to push the broom.
  - In this case, the average (over ten seconds) force was approximately 0.25 Newtons.

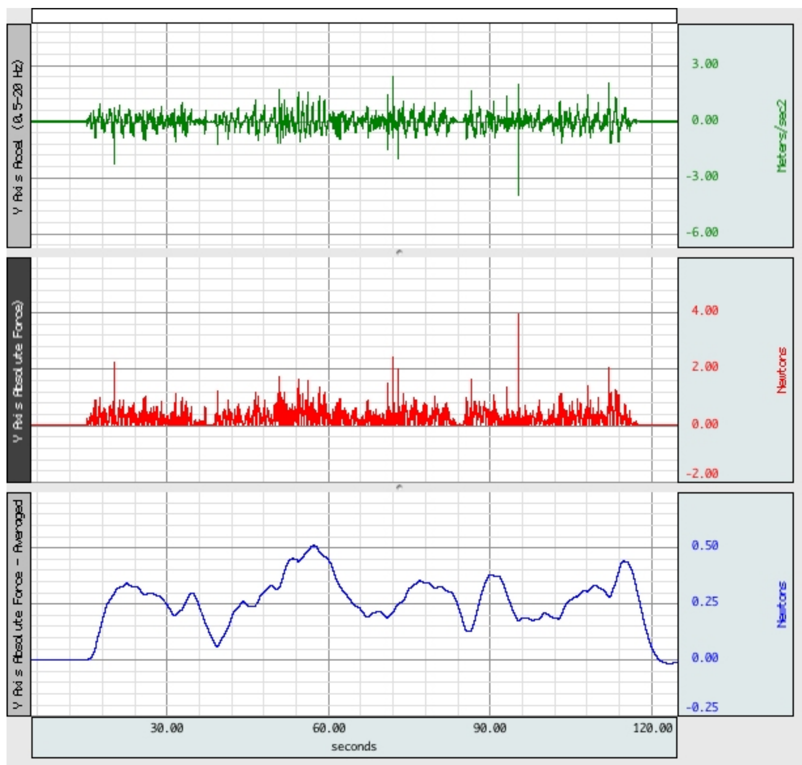

Figure 4: Y axis Force Measurements

This graph examines the Y axis velocity data and employs it to calculate the related forces involved along that movement axis.

The formula e=½mvv is used, with the assumption that the lightweight broom weighs 1 kg.

- Top waveform is calculated velocity.
- Middle waveform is calculated energy (e=½mvv).
- Bottom waveform indicates the average (side to side) energy used by the subject to push the broom.
  - In this case, the average energy was approximately 2 milli-joules (mJ). This small number would imply that very little energy was expended by the subject along the Y axis of movement.

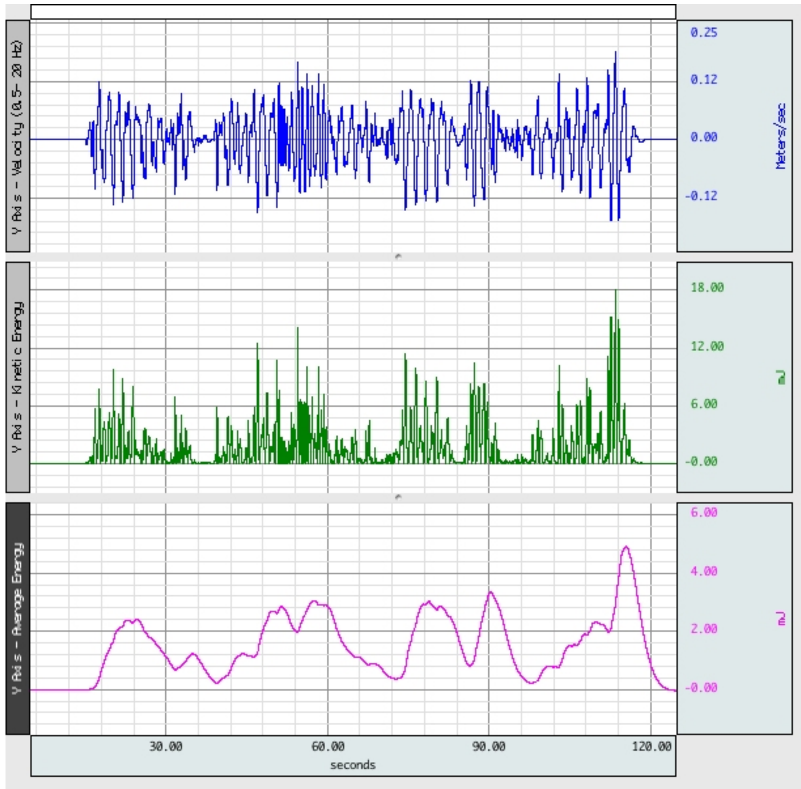

Figure 5: Y axis Energy Measurements