

The Use of Wireless Instrumentation for Stability Testing

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Abstract

In the light of all the medical research that is being pursued in our world today to find the answers to the ills, diseases, health problems, and accidents to which humankind is prone; it seems strange that very little time and funding is at hand to research how falls can be prevented. It is time we begin to find some answers. By working with a person's gait and discovering what happens to the roll, pitch, and yaw as a person walks we can begin to develop skills to use in rehabilitation so that an individual can walk more safely; skills that can correct the roll, pitch and yaw when a deviation is found that causes difficulty when walking. What we see here in this paper is only the beginning.

The first aim is to establish a standardized method for stability testing. A second aim is to determine a method of analysis of the recorded data.

A series of tests were conducted for the benefit of residents of a retirement community. The long term goal is to aid in fall prevention.

An inertial sensor was used to obtain real time data during the tests, and these data were recorded and saved for later evaluation.

Background

The National Council on Aging publishes this fact sheet, "Falls are the leading cause of fatal and non-fatal injuries for older Americans. Falls threaten seniors' safety and independence and generate enormous economic and personal costs. However, falling is not an inevitable result of aging. Through practical lifestyle adjustments, evidence-based falls prevention programs, and community partnerships, the number of falls among seniors can be substantially reduced."

The following is an excerpt from the Johns Hopkins website. It is a synopsis of the current situation. "Falls can result in serious medical complications including hip fractures and head injuries. In many cases, those who experience a fall have a hard time recovering and their overall health deteriorates. Statistics show that more than 40% of people hospitalized from a hip fracture do not return home and are not capable of living independently again. The good news is that, with adequate knowledge, falls can be prevented."

This stability testing method is an attempt to further the cause of "adequate knowledge". Society needs a method of standardized testing and data evaluation. This method may be proactive in measures of mitigation of human suffering and cost of care.

Testing Methodology

In the absence of standardized testing, the fitness coordinator devised a testing routine that included a series of segments. First, the subject was requested to walk forward through the length of the fitness center (a distance of approximately 30 feet), turn 180 degrees, and walk forward to the origin.

An inertial sensor was used to obtain real time data during the testing. These data were recorded and saved, and then were exported to a spread sheet program for easier comparison as charts showing the entire scope of each test. For an example of an actual test see Figure 1. In Figure 1, it can be seen that as the subject turned to walk in the opposite direction, the yaw values change by 180 degrees. The plots of roll and pitch continued in a similar pattern as before.

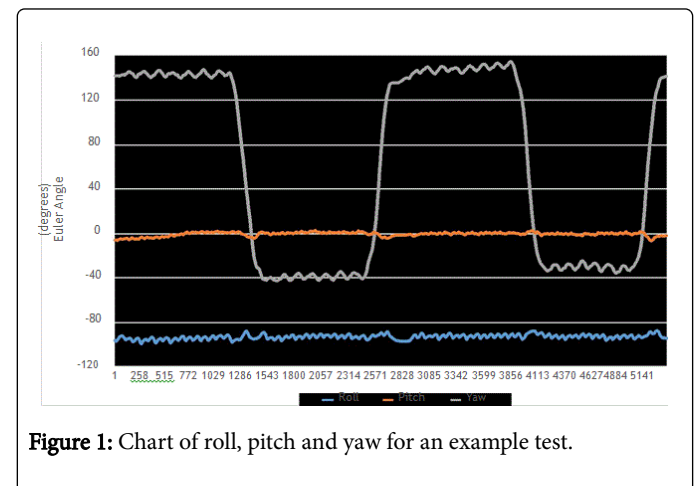


Figure 1: Chart of roll, pitch and yaw for an example test.

Instrumentation

The inertial sensor was obtained from Xsens Technologies BV (Netherlands). Model MTw was used during these tests. This sensor includes accelerometers, gyroscopes, and magnetometers in three planes. The battery powered sensor communicates wirelessly with a

dongle placed in a USB port on the host computer. The real time data was shown on the host computer screen, was recorded and saved for later evaluation.

Data Analysis

The recorded data included roll, pitch and yaw as well as time stamp information. Rotation around the front-to-back axis is called roll. Rotation around the side-to-side axis is called pitch. Rotation around the vertical axis is called yaw.

Each test resulted in more than 15,000 packets of data. After 35 tests, over one-half million packets of data were recorded. The abundance of data has been described well by one author who is quoted as writing, "We are awash in data, but have no information." Peter Drucker, author of texts on management, has said "Information is data endowed with meaning and purpose." Our challenge is to find nuggets of golden information.

Software provided by the manufacturer of the inertial sensor is a powerful tool to merge measured data. The most informative data is derived from the Euler angles using Kalman filters. The X, Y and Z values of roll, pitch and yaw are plotted versus time so that a qualitative evaluation may be made, particularly when comparisons are made between subjects.

The recorded data was exported as a delimited text file to a spread sheet program. The spread sheet program provided import of the delimited data conveniently to columns in the spread sheet. Analysis of yaw was necessarily done in segments coinciding with the testing segments. Roll and pitch were analysed throughout the recorded test [1-3].

The analysis method applied this novel technique. An average of each data file was determined, and subtracted from the recorded data. This resulted in a listing of excursions from average as plus and minus values.

The root mean square values were then calculated, and an average determined. This same procedure was followed for each yaw segment, and for roll and for pitch. This analysis procedure resulted in concise representative values.

The values were added and then compared for all volunteer subjects. These reduced values are the nuggets we are looking for.

A second method was employed to obtain additional values that may be compared to the results of the first analysis method. The second method calculated regression values for ranges of significant data. For reasons of comparison, the reciprocal of regression was normalized. This value was compared to the root mean square values described above.

The result was a surprising correlation of values for the two methods. A stacked bar graph showing the results of 44 tests is shown as Figure 2. Note that the upper four tests indicate some problems with the walking gait.

Figure 2 is included to show the relative normalized RMS and the reciprocal of regression values in a single chart.

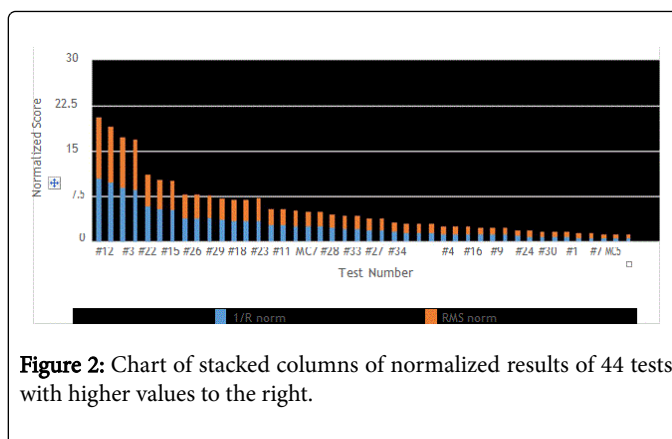


Figure 2: Chart of stacked columns of normalized results of 44 tests with higher values to the right.

Observations and Conclusions

In the data analysis section above, it was noted that the upper four tests in Figure 2 indicate some problems with the walking gait. Therefore, four figures were added that show a portion of each test. These figures do not include the portion where the subject turns to walk in the opposite direction. Intuitively, it is expected that the figures would show considerable deviations of one or more variables.

Figure 3 shows test number MC8, the test with the highest score. Yaw shows large deviations although basically periodic in nature. Roll and pitch are both irregular. The subject may have been using a walker during this test.

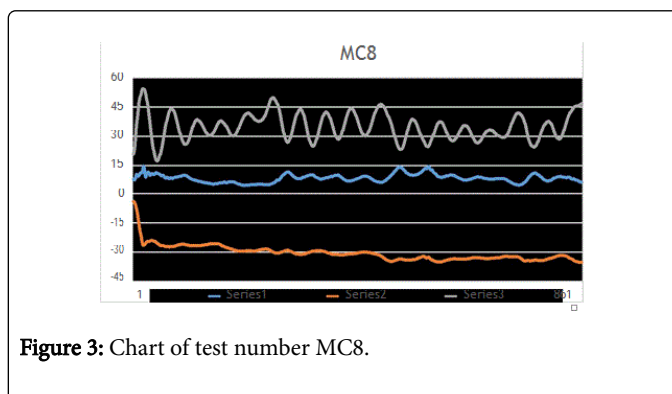


Figure 3: Chart of test number MC8.

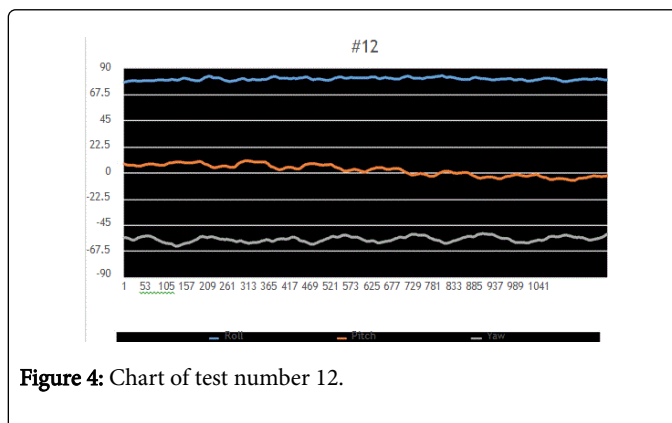


Figure 4: Chart of test number 12.

Figure 4 shows the test with the second highest score, test number 12. The pitch and yaw show the highest deviations. This is an unusual gait.

Figure 5 shows the next higher test, test number 31. Pitch is quite smooth, roll is quite periodic, but pitch is very irregular.

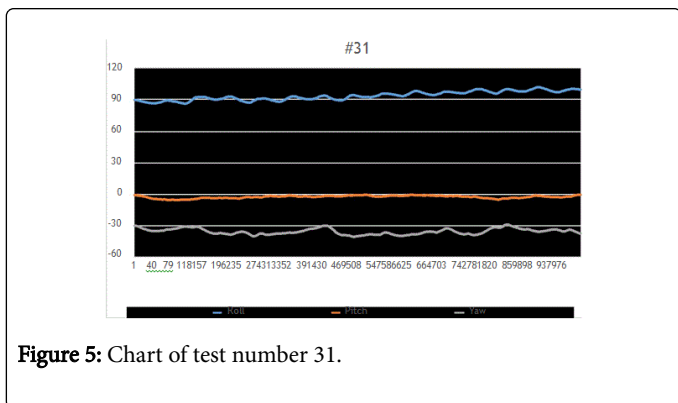
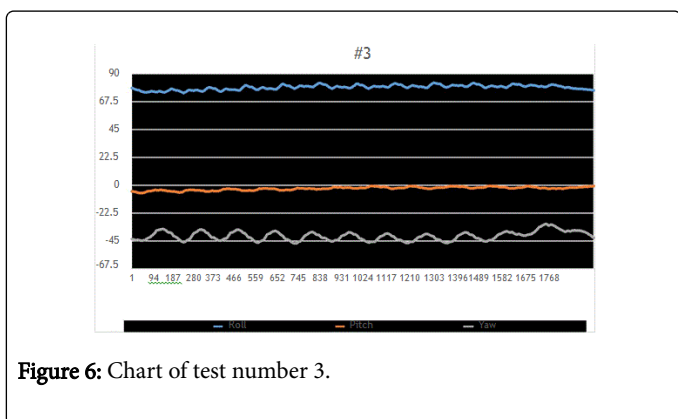


Figure 6 shows the fourth higher test measured by the scoring method. Again pitch is quite smooth, there is considerable periodic yaw, and roll is somewhat irregular.



An additional four figures were added to illustrate the four lower tests. The figures show a similar portion of the test as above. Intuitively, it is expected that the figures would show very small deviations of all variables.

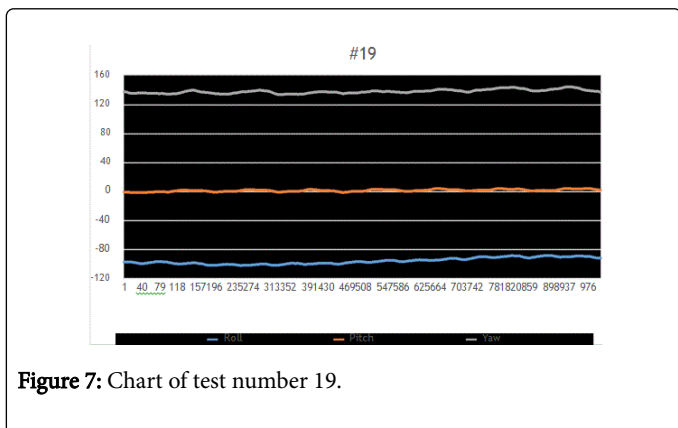


Figure 7 shows test number 19. This test shows a very smooth walking gait as seen by small deviations in roll, pitch and yaw.

Figure 8 shows test number MC5. The chart appears different because the three variables were zeroed prior to taking data. However, there are only small deviations in roll, pitch and yaw.

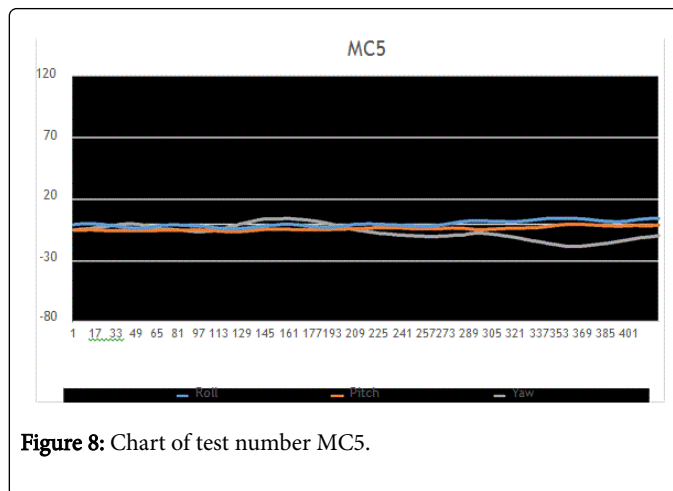


Figure 9 shows test number 25. Again, the three variables are quite smooth with small deviations.

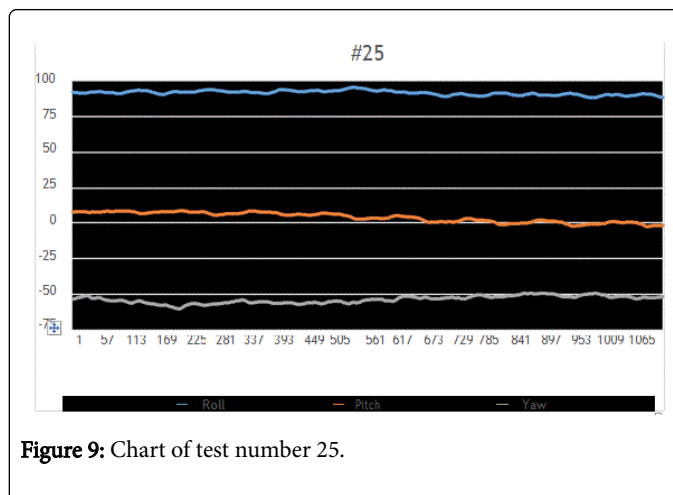
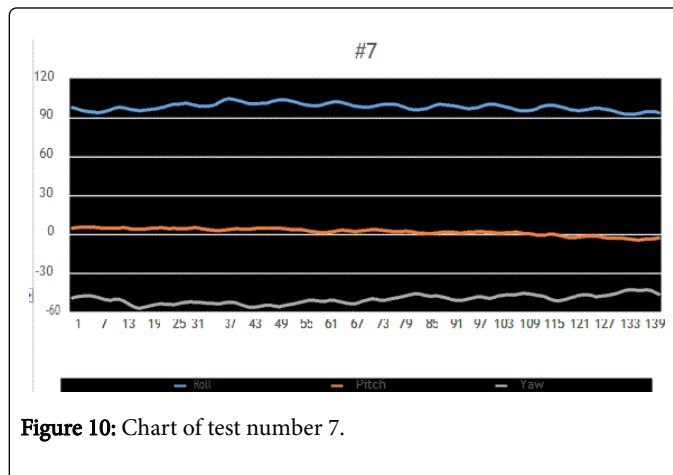


Figure 10 shows test number 7. The chart shows smooth pitch, moderate roll, and somewhat irregular yaw.



The overall conclusion is that tests of this nature may be a convenient method to evaluate residents, who may over time require the assistance of a cane, walker, or rehab care prior to the catastrophe of a fall.

2. (2013) Xsens Technologies BV. MTw User Manual.
3. Van Nimmen K, Lombaert G, Jonkers I, De Roeck G, Vanden Broeck P (2013) Characterisation of walking loads by 3D inertial motion tracking. J Sound Vib 333: 1-15.

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1. Bachmann H, Ammann W (1987) Bachmann vibrations in structures: induced by man and machines. IABSE-AIPC-IVBH.