ActiGraph White Paper

Estimating Human Position with the ActiGraph GT3X Triaxial Activity Monitor

With the introduction of 3-axis accelerometers, it is now possible to expand beyond gross measurement of physical activity and classify activity types. The ActiGraph GT3X Triaxial Activity Monitor takes a first step in this direction with an inclinometer feature that indicates whether a subject is standing, sitting or lying down when the device is worn at the hip as well as indicating that a device is not being worn at all. This feature provides an additional data point for interpretation of activity levels by researchers and health professionals and is also included in the ActiSleep and 3-axis ActiTrainer Research Model devices.

In the absence of activity, a 3-axis accelerometer senses the acceleration due to gravity. This value is effectively a down vector from which the orientation of the device (with the exception of heading) is determined. Equations 1 and 2 define the calculation used to obtain two important angles for determining a subject's posture where *x, y,* and *z* represents the acceleration along each axis.

Equation 1

$$\theta_y = \cos^{-1}\left(\frac{y}{\sqrt{x^2 + y^2 + z^2}}\right)$$

Equation 2

$$\theta_z = \cos^{-1}\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right)$$

When worn on the hip and perfectly vertical, the y-axis alone should contain the total acceleration due to gravity. As a subject inclines, the offset angle (θ_y) increases. If the device is not being worn, then one expects the z-axis to reflect the total acceleration due to gravity as the device rest on a table-top for example. Therefore, the addition of the z-axis offset angle (θ_z) is required to distinguish between lying and off. Figure 1 contains examples of this y-axis offset angle in the standing (top-left), sitting (top-right), lying (bottom-left), and z-offset angle in the off (bottom-right) positions.

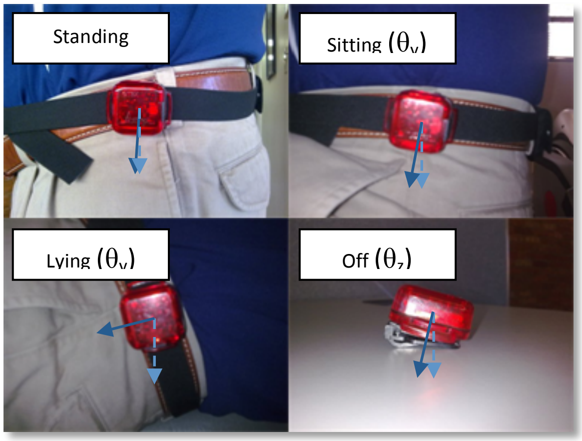

Figure 1

Optimal angle thresholds are required to correctly estimate the posture for the widest range of users. The acquisition of this data involved collecting 30 Hz raw accelerometer data using a GT3X Activity Monitor from numerous subject's for analysis. Each subject was instructed to stand, sit and lie down for 5 minute periods for a total of 15 minutes worth of data. Each 30 Hz sample was then categorized and a computer script was used to determine the optimal θ_y value for standing, sitting and lying by minimizing the error between the known inclination and the estimate. Raw data was collected using several GT3X devices with and without belt clips and pouches with belt loops and the same script was used to determine the optimal θ_z value.

When activity exceeds six counts per second, the user is assumed to be standing due to the high activity values and thus the inclination angles are ignored. Otherwise, $\theta_y < 17^o$ is considered STANDING, $17^o < \theta_y < 65^o$ is considered SITTING, and $\theta_y > 65^o$ is considered LYING unless $\theta_z < 22^o$ when the unit is OFF. Internal tests have regularly surpassed 95% accuracy with exceptions for outliers with posture at the extremes (e.g. one subject sat up as straight as to indicate standing while sitting). All parameters of the algorithm will be configurable by the ActiLife software in case broader research finds more optimal values.

Estimation of human position using 3-axis accelerometers adds further value to the already solid actigraphy performance of the ActiGraph GT3X. With knowledge of a subject's disposition, researchers and health professionals can garner further insight from the already accurate activity levels, energy expenditure and step counting. Detecting off, lying, sitting and standing positions is just a first step in even more detailed activity classification to be achieved by the research community using high data rate 3-axis activity monitors from ActiGraph.