Combination of a Gyro Sensor and Accelerometer for Stride Length Measurement

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Introduction: Methods currently available for the measurement of walking speed and/or stride length are somewhat limited. Systems that use optical methods (photocells or videography) or instrumented carpets (*GaitMat*, *GaitRite*) can only be used in the laboratory and are hence unsuitable for prolonged ambulatory monitoring. Others, e.g. multimemory stopwatches or ultrasound require an independent observer. Conversely, portable pedometers (e.g. *Nike* SDM[Triax 100, *Fitsense* FS-1 Speedometer) are restricted to measurement of cadence (some *report* velocity, but actually estimate it assuming a fixed stride length).

Statement of Clinical Significance: Accurate measurement of the speed and/or stride length of gait (walking, jogging, running) is essential for functional assessment. A portable device capable of being carried inconspicuously would facilitate long-term ambulatory measurements in the home, workplace and community.

Methodology: The combination of a gyro sensor (ENC-03J, Murata, Japan) and bi-axial accelerometer (ADXL202, Analog Devices, MA) were incorporated into an instrumented insole (Kirtley, 2002). The gyro output, ω, following integration, tracked the angle of the foot, ϕ (Mayagoitia et al, 2002), and this angle was then used to remove the gravity vector from the accelerometer signal and derive the forward acceleration, a_x (fig. 1). This was then double-integrated to obtain the horizontal distance traveled by the foot, *d*, each step. An auto-nulling algorithm (Williamson & Andrews, 2001) was implemented each time the foot was motionless during stance phase, by detecting when the vector sum of the acceleration components was approximately equal to the gravitational constant, *g*. At these times, the angle of the foot, ϕ_o, was determined from the accelerometer ($\tan \phi_o = a_x/a_y$).

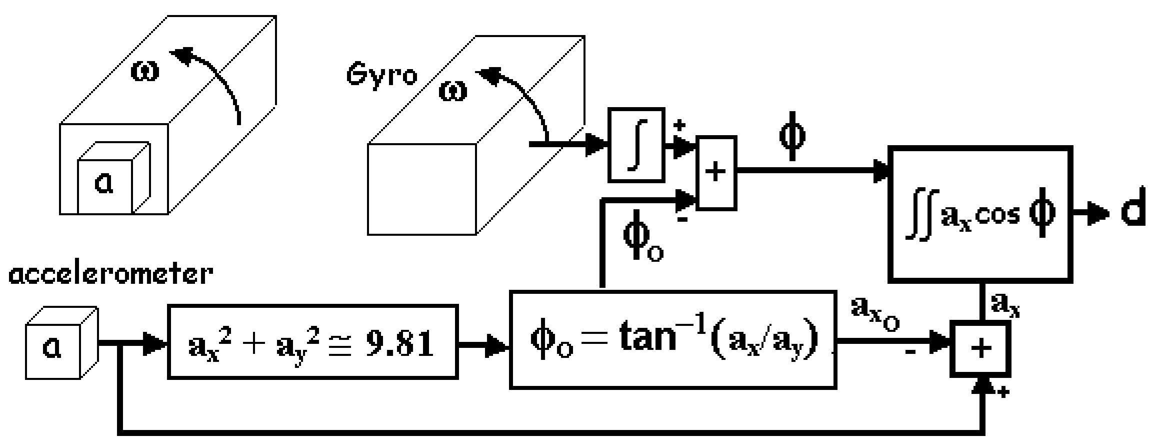

Fig. 1: Algorithm used for deriving distance traveled from gyro and accelerometer data.

To assess the accuracy and robustness of the method, five subjects were asked to walk over a known distance (9 m) at three speeds (natural, slow and fast).

Results: A typical sequence of steps is shown in fig. 2. The percentage errors in the distance recorded by the gyro/accelerometer combination is reported in fig. 3.

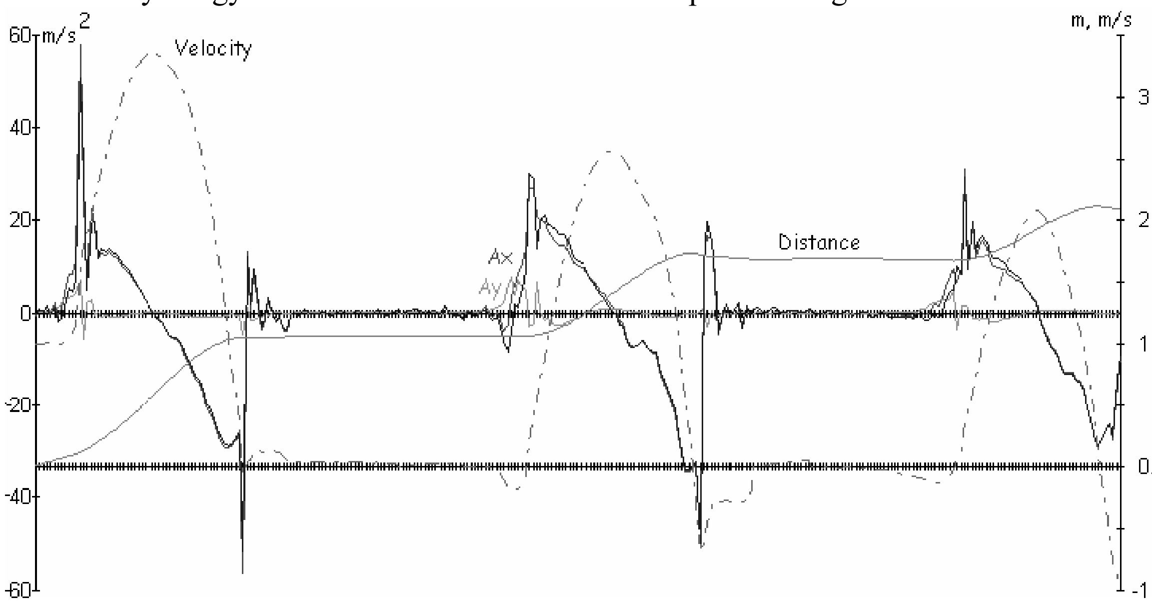

Fig. 2: Typical sequence of steps, showing derivation of forward velocity and distance by integration. Individual step length is shown as the distance between each plateau.

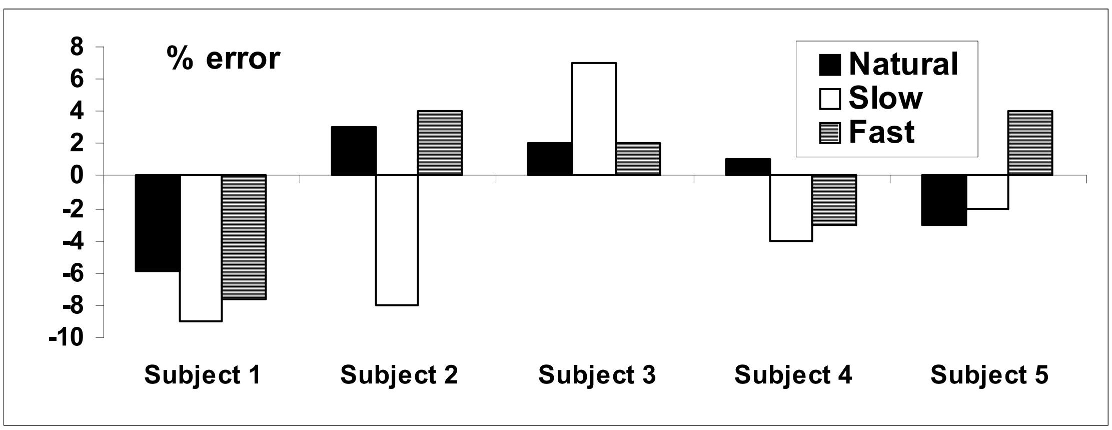

Fig. 3: Percentage error in stride length estimation.

Discussion: An inertial-based measurement system has been described for the measurement of stride length and walking speed. Accuracy was acceptable (within 10%), but varied somewhat between subjects, and it was generally worse at slower speeds. It is possible that this might be improved by tuning the auto-nulling algorithm further.

References:

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Mayagoitia RE, et al (2002) Journal of Biomechanics 35 (4): 537-542.
Williamson R, Andrews BJ (2001) Med. Biol. Eng. Comput. 39(3):294-302.