

GAIT IDENTIFICATION AND RECOGNITION SENSOR[□]

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SUMMARY

One of the major obstacles in developing reliable walking neural prostheses is poor performance of the sensors which are used for gait phases identification. Improper functioning of these sensors causes wrong stimulation pattern selection and wrong stimulation sequencing of the walking neural prostheses. These malfunctions often cause unstable walking patterns in patients that are using the prostheses. Sensors that are commonly used for gait phase identification are: foot switches, force sensitive resistors (FSRs), accelerometers, pendulum resistors and goniometers. Since none of these sensors is capable of identifying gait phases with accuracy greater than 95 %, a decision was made to develop more reliable gait identification sensor.

A new gate identification sensor, which consisted of three FSRs, an inclinometer and a rule-based observer, has been proposed. Every 50 ms from the FSRs and the inclinometer readings the proposed sensor identified one of the following gait phases: heel off, swing phase, heel strike and mid stance. The experiments conducted with able-bodied and disable subjects showed that the proposed sensory system detected the above gait phases with reliability greater than 99 %. This foot sensor was capable of distinguishing walking sequences from weight shifting during standing, and it did not give false gait annunciation when the instrumented foot was sliding during standing.

Our future research is aimed at further improving the foot sensor packaging, and sensor's robustness to different environmental conditions and shocks.

STATE OF THE ART

In order to design a walking neural prosthesis, which can automatically detect gate phases and accordingly select stimulation sequences, one has to have a reliable gate recognition sensor. One of the first foot sensors proposed was a heel switch [1] which was used to detect the heel strike during normal gait. Advanced walking neural prostheses require information about other gate phases in addition to heel strike. Hence, the heel switch is not an appropriate sensor for this application. Second approach suggests that at least 3 FSRs, placed in a shoe sole, can be used to detect the most important gate phases [2, 3]. Experiments conducted in our laboratory clearly showed that the FSRs alone cannot reliably detect gate phases. This system has a number of problems, out of which identifying weight shifting during standing as walking pattern is probably the most severe one. In order to

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resolve this problem some researchers proposed using goniometers, in conjunction with FSRs, which are attached to hip, knee or ankle joints [4, 5]. Experiments conducted in our laboratory demonstrated that goniometers and FSRs together do not provide reliable gate identification. In particular, this sensor configuration generated wrong gait identification when subjects were making short brakes or rests during walking. Since none of the existing foot sensors is capable of identifying gait phases with sufficient accuracy, a decision was made to develop more reliable foot sensor.

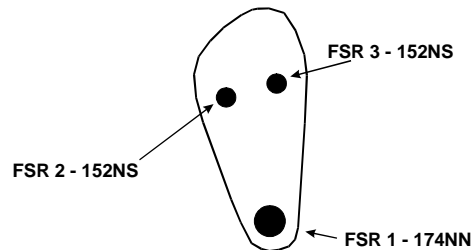


Figure 1: Position of the FSR's in the shoe sole

MATERIALS AND METHODS

The proposed foot sensor consisted of three FSRs, an inclinometer and a rule-based observer. One 174NN and two 152NS FSRs, manufactured by Interlink Electronics Inc. [6], were used to measure forces generated by subject's heel and metatarsal bones during walking. The FSRs were placed in the shoe sole as indicated in Figure 1. Time response of the FSRs was 2 msec.

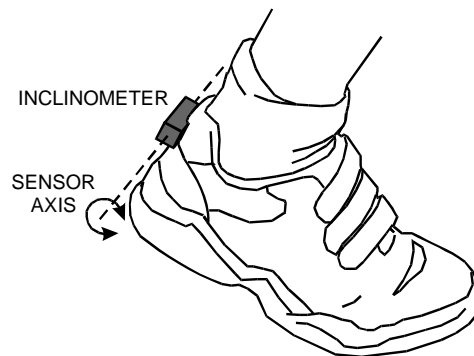


Figure 2: Position of the inclinometer

In house developed inclinometer was used to measure relative position of the heel with respect to the walking surface. The inclinometer consisted of a gyro sensor ENC-05A, manufactured by Murata [7] (see Figure 2), and an integrator which calculated the position of the heel from the raw gyro data. The gyro was attached to the shoe heel and its sensory axis was parallel to the walking surface (see Figure 2). The time response of the inclinometer (combined time response of the gyro and the integrator) was 30 msec.

The rule-based observer was designed to identify mid stance, heel off, swing phase and heel strike gate phases, and was implemented using Hitachi SH7032 evaluation board. The proposed observer functioned as follows. Once the sensor was turned on, a subject instrumented with the sensor had to stand still for one second before it made the first step.

During this period of time the observer automatically reset FSRs' and inclinometer readings and set them to initial values (FSRs = ON and inclinometer angle = 0 deg). After the reset, the rule-based observer shifted into gate recondition mode described in Figure 3. Note, except for mid stance, all other gate phases could be identified only if the previous gate phase was successfully identified. This feature was introduced in order to prevent false gate phase identification. In addition the observer's algorithm was enhanced with an adaptive routine which compensated for FSRs' drifts. Time constant of this algorithm was 11 sec.

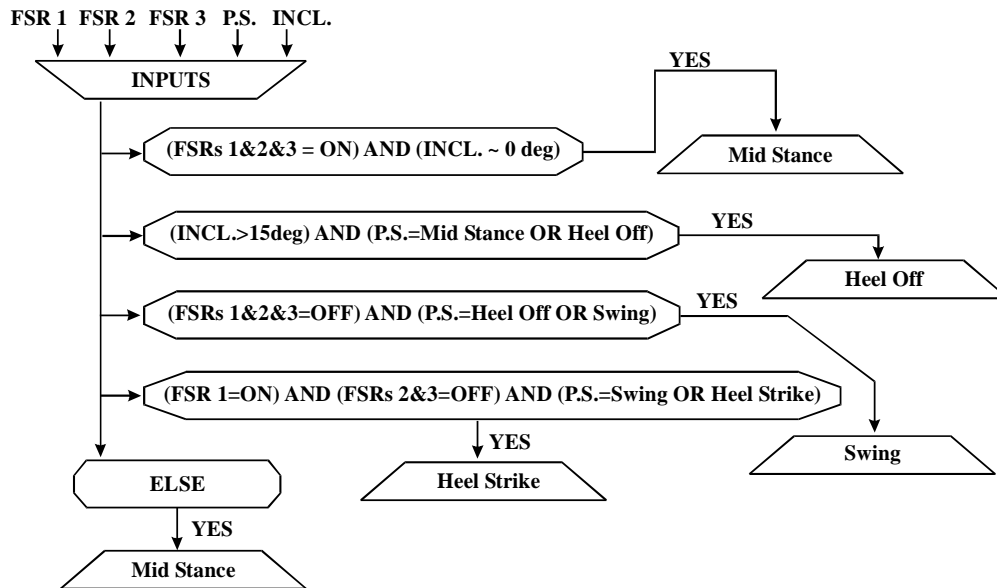


Figure 3: Observer's gate recognition algorithm (INCL. represents the inclinometer angle in [deg] and P.S. represents the previous state of the sensor)

RESULTS

Preliminary experiments performed with 10 able-bodied subjects and 10 disabled subjects showed that the proposed foot sensor can identify mid stance, heel off, swing phase and heel strike with reliability greater than 99 %. The proposed foot sensor was capable of distinguishing walking sequences from weight shifting during standing, and it did not give false gait annunciation when the instrumented foot was sliding during standing. It is important to mention that subjects that were trained to use the sensor achieved better results than the subjects which used the sensor for the first time. Representative experimental results obtained with the proposed sensor are given in Figure 4.

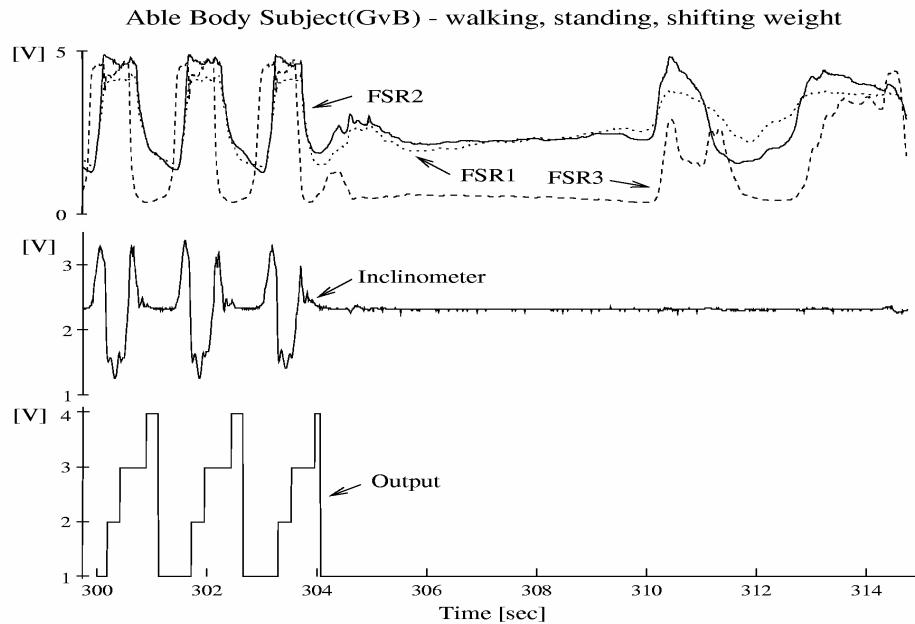


Figure 4: Gait pattern recognition - intermittent walking of an able body subject

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