APPLICATION OF THE ACCELERATION SENSOR IN FUNCTIONAL ELECTRICAL STIMULATION FOR THE RESTORATION OF GAIT IN STROKE PATIENTS


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Abstract – Our advances in the detection of the swing phase in foot drop gait using an acceleration sensor was described. The heel sensor system was used for the restoration of foot drop gait with functional electrical stimulation (FES) in our group. However there are still complications when placing the heel sensor. To replace the heel sensor, we measured the acceleration of the thigh during gait using an acceleration sensor. The detector was synthesized using a rule induction algorithm, by the name of, Neural Network. We have applied a signal for heel contact in a gait using the heel sensor before training with the Neural Network. The accuracy of the Neural Network detector was compared with a swing phase detector based on the heel sensor. The Neural Network detector was able to detect similarly the swing phase in the heel sensor. The largest difference in timing was less than 60 msec. An acceleration sensor, which was put on the thigh, was useful in detection the swing phase.

Keywords: functional electrical stimulation, hemiplegia, foot drop gait, sensor, Neural Network

1. Introduction

Functional electrical stimulation (FES) has been used to restore the gait of stroke patients. The most common method of control uses foot switches, as originally proposed by Liberson et al., however this requires wires or telemetry to connect the switch to the stimulator.[2] We have been preventing foot drop gait, which is caused by stroke, with percutaneous intramuscular FES using footswitches under the heel as in the Akita Heel Sensor System (AHSS) invented in 1996.[1], [3] AHSS is useful for foot drop gait patients. Potential improvements include: ease of installing systems on patients’ heels, durability, and cosmetics. In 1996, Dai et al. reported that the tilt sensor needs to be put on the calf in order to prevent foot drop gait with FES using tilt sensors.[4] A miniature foot drop stimulator was designed with a magnetoresistive tilt sensor built in; no external sensor cables are required. Theory has it that if the acceleration sensor is put on the thigh, we will be able to detect steps in the gait. Patients can also put the sensors on more easily. To replace the heel sensor, various sensors have been used in research for restoration of foot drop gait. The rule induction algorithm was introduced to adapt the stimulation to foot drop gait. Kostov et al used ALN to implement a stance swing detector for FES control of hemiplegic gait. [5] We present our advances in the detection of the swing phase in foot drop gait using an acceleration sensor.

2. Purpose

The purpose of this study was to evaluate the possibility of detection in normal and footdrop gait cycles using an 2-axis acceleration sensor, which has been put on the anterior portion of the thigh.

3. Subjects

Subjects were 5 healthy males, average age was 26 (23–29) years old, 1 stroke patient (a 56 year old, female) was also measured. Her classification of function was Brunnstrom 5.

fig. 1 Acceleration sensor (ADXL 202)
4. Materials

The acceleration sensor, which was put on the affected side of thigh, was an ADXL 202 (Analog Devices, Inc.) (fig. 1). The acceleration sensor was mounted on the ADXL 202 evaluation board. It could measure the acceleration change in two axes. It was put on one side of the anterior middle portion of the thigh. We measured the changes in acceleration, which were the sagittal direction of the thigh and gravitational direction of the thigh during gait. The onboard amplifier was set with a gain of 2 giving a range of +/- 2g. The signals were recorded using ND-2000 (KEYENCE, Inc.) with the sampling rate set at 100 Hz.

5. Method

An acceleration sensor was put on the lateral middle portion of the thigh (fig. 2). We measured the acceleration of the thigh during gait using an acceleration sensor and the timing of heel contact during gait using a heel sensor simultaneously. The heel sensor was placed under the heel to provide reference points for the step cycle. Subjects walked barefoot on the floor in the lab area. Step length was about 50 cm. The number of gait cycles was about 50 gait cycles for each data.

These data were taken in personal computer, and processed to the learning form. The acceleration data was processed to the input data, and heel data was processed to the target data for Neural Network training purposes. We required bias and weight of Neural Network using MATLAB, Neural Network Toolbox (The MathWorks, Inc.). We made Neural Network including weight and bias using C language, and forward a program to a microcomputer. A microcomputer was made output signals for stimulating in swing phase using the Neural Network program, at real time. The accuracy of output data using microcomputer was compared with output data using heel sensor.

6. Results

In normal subjects, the Neural Network detector was similarly able to detect the swing phase in the gait cycle, when heel sensor detected (fig. 3,4). The largest difference, which was the timing of swing phase, was less than 60 msec. In a stroke patient, Neural Network detector was also able to detect the swing phase in the gait cycle. The obtained control signal sometimes contained sporadic stimulation spikes in the stance phase (fig. 5). The largest difference, which was the timing of the swing phase, was less than 80 msec.

7. Discussion

Using the Neural Network, we were able to detect the swing phase only putting on an acceleration sensor. The largest difference, which was the timing of swing phase, was less than 60 msec. These differences were within 5% in swing phase, and were considered to be negligible for the overall performance of the foot drop restoration system. In this study, we actually measured a stroke patient’s gait, which was foot drop and circumduction gait. The stroke patient’s gait was apparently different from the timing of the normal gait events, the length of swing phase, the angular change of hip and knee joint, and the acceleration change of the
thigh in the affected side. In spite of these differences, the Neural Network detector was similarly able to detect the stroke patient’s swing phase in the normal subject’s case. The possibility was suggested that an acceleration sensor, which was put on the affected side of the thigh, could also use in the case of using the heel sensor system. The Neural Network detector can correspond to predict the beginning of gait events. We think that this system is equivalent to restore foot drop gait for each stroke patient flexibly.

8. Conclusion

An acceleration sensor, which is put on the thigh, can be used to measure a gait cycle. This study suggests that putting an acceleration sensor on a stroke patients' thigh improves the FES procedure and help to restore gait in stroke patients.

References