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# The Development of EVAL Cane - A Smart Cane for the Evaluation of Walking Gait and Walking Environment

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**Abstract**—This paper proposed a low-cost, non-intrusive and multi-function smart cane, *i.e.*, EVAL Cane, for the elderly people or fragile people. Several sensors such as accelerometer/gyrometer, ultrasonic sensor, force sensitive resistor (FSR), and temperature sensor were instrumented on the cane to collect the data of user’s walking gait and walking environment. Although these sensors were not installed on the human body directly, the user’s gait feature can be described by certain of them such as accelerometer and FSR, that means the user’s gait can be analyzed and evaluated during the walking with the cane. Besides, based on the data analysis of accelerometer, we can also detect unwanted events such as falls during the walking, which is helpful for the monitoring of user’s health. In addition, the cane has an ultrasonic sensor used to detect an obstacle in front of the cane and this sensor will work together with a buzzer in order to give a sound signal to the user when an obstruction is detected in front of him/her. The buzzer will also make a sound when a fall is detected. Moreover, the environmental temperature of the cane can be measured and be displayed on a LCD screen to the user along with the number of steps taken and the battery percentage level of the device. In a word, EVAL Cane is capable to monitor the user’s walking, detect the surrounding environment, give output back to the user, and to collect data while in use for further analysis.

**Index Terms**—Smart cane, gait analysis, health monitoring, elderly, IoT

## I. INTRODUCTION

The use of a walking cane is common among elderly people or fragile people who have lower back or hip pain and also people who have trouble seeing. Normally in these type of situations the user will use the cane for long time periods and in some cases even for the rest of their life. In order to develop more functions on the cane for users, their doctors or guardians, many smart canes instrumented with sensors were developed to satisfy users’ different needs. For example, [1] proposed a sound and touch based smart cane. The design was incorporated with Bluetooth enabled obstacle detection module, supported with heat detection and haptic modules. The ultrasonic range finders helped in detecting obstacles. Similarly, [2] also developed a smart cane with distance measurement system for blind people. An ultrasonic sensor was used to measure distance from the obstacle and an

earphone was used to alert it. In order to alert obstacles more effectively, [3] added a model-based state-feedback control in smart cane. Besides, since the internet of things (IoT) technology is growing quickly, many connected devices were developed. For example, WeWALK is a connected cane that can be paired with smart phone to get navigation and also be integrated with Voice Assistant and Google Maps [4].

The above studies about smart cane focus on detection of obstacles, alert output, navigation and so on. However, for the cane users such as the elderly people or the fragile people who had difficulty walking, these functions are not sufficient. What they need may be gait analysis, which can offer walking quality indicators for their doctors to evaluate their level of mobility, even health state because some maladies can influence the gait feature such as Parkinsons disease. In our previous studies [5], [6], a rollator walker was instrumented with encoders and a 3D accelerometer/gyrometer to analyze the walking of young and elderly people. The results showed that users’ steps could be detected by using the zero-pass moments of angular velocity collected from the accelerometer/gyrometer. Thus many usual walking gait indicators such as step number, stride length and walking speed were obtained, that means it is possible to do gait analysis by using this kind of device instrumented with sensors. In other word, it is possible to evaluate users’ walking level and monitor their health state. Moreover, since the sensors were not installed on the human body directly but on a mobility device which could be used everyday by the elderly, this method is not intrusive and low-cost for users. Therefore, with the same objective we designed EVAL Cane, which is also installed a 3D accelerometer/gyrometer for gait analysis. Besides, other functions such as detection of falls, detection of obstacles, alert output and evaluation of walking environment are also realized on our EVAL Cane.

## II. DESCRIPTION OF EVAL CANE

This smart cane is designed based on an original frame but with a few extra features added to it that will make the cane capable of monitoring its utilization and environment.

As shown in Fig. 1, the inputs of the whole system, *i.e.*, the sensors installed on the cane, are an accelerometer/gyrometer, a temperature sensor, an ultrasonic sensor and a force sensitive Resistor (FSR) respectively. Obviously, our cane equipped with FSR can collect more information of user's walking compared with other smart canes that only equipped with accelerometer or ultrasonic sensor. The FSR is a resistor that changes its resistance if pressure is put on it. When there is no force applied on the FSR the resistance is extremely high acting as an open circuit. As pressure is put on it the resistance will decrease. The more the pressure is, the less is the resistance. Here FSR is installed on the top of the cane's handle so it can detect if users acted on the cane and how much pressure was put, which is helpful for the gait analysis.

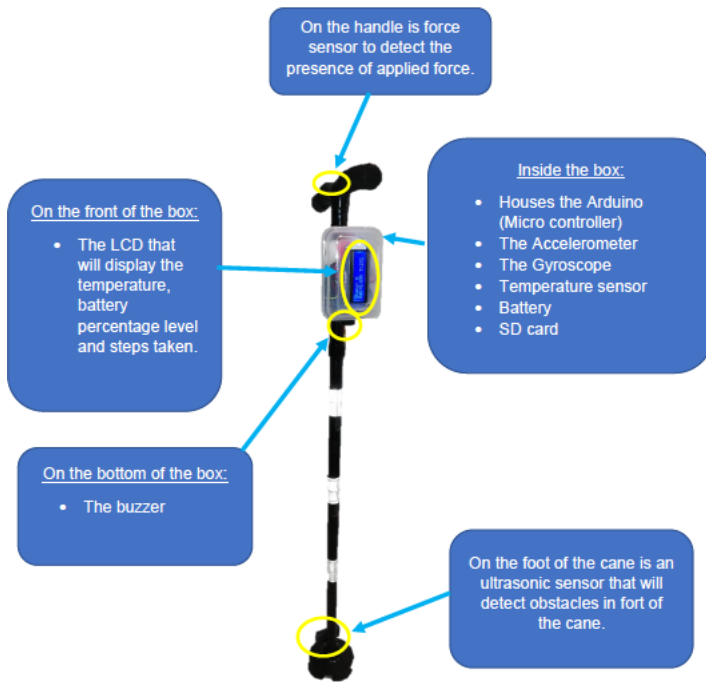


Fig. 1. The EVAL Cane.

For the outputs of the cane, we installed a small LCD Display and a Buzzer at present. The LCD Display was equipped on the top of the cane in order to offer some information of the cane, user's walking, and the walking environment. Now it can show the battery percentage level of device, the number of steps finished and the temperature. However, which information will be displayed on LCD can always be reset according to the needs of users. In addition, another output is a Buzzer. It works when an obstacle or a falling is detected, and two different voices are set for the two cases respectively.

To collect the sensors' data and do further analysis, all the sensors were connected with Arduino UNO as a microcontroller. All the measurement that it takes will automatically be updated in its internal data registers. In summary, a block diagram used to describe the functions of our cane is shown in Fig. 2.

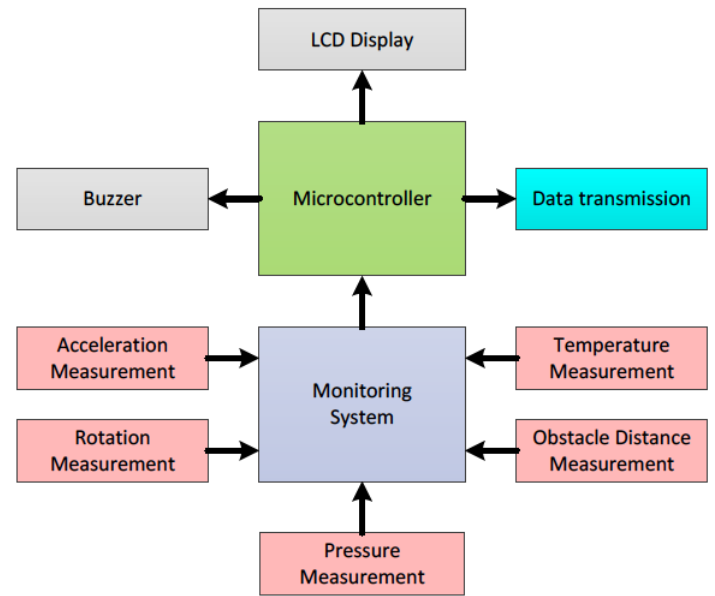


Fig. 2. The functions of EVAL Cane.

### III. RESULTS

We tested the cane and confirmed that all the expected functions such as gait analysis, detection of falls and obstacles, and alert output, can be realized. For example, Fig. 3 shows the data of FSR during the walking of a user. We can clearly see that its pattern is cyclic, which can be used to detect the user's steps precisely. In fact, since the user only applies force on the handle of cane for one support leg during the walking, one cycle of the FSR's data means that the amount of steps finished by the user is two. Next, the walking quality indicators can be calculated or estimated by using the data of accelerometer, and the same method has been presented in our previous studies [5], [6]. Besides, we tested the fall detection by using the cane, and the data of accelerometer when the cane was suddenly dropped on the ground is shown in Fig. 4. It can be seen that there is an immediate and large change on the data of accelerometer. In the microcontroller, this change is regarded as a fall and the Buzzer will be activated.

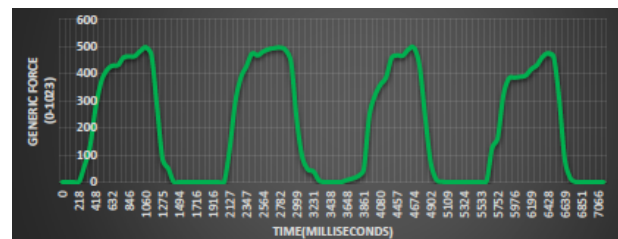


Fig. 3. Data of FSR during the walking of a user.

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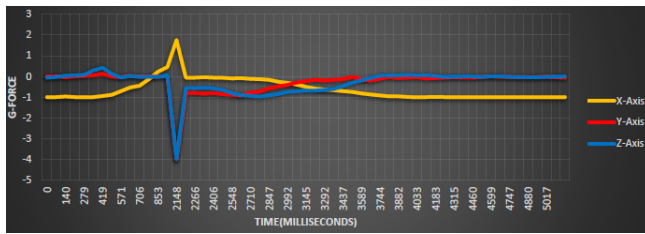


Fig. 4. Data of accelerometer when the cane is suddenly dropped on the ground.

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