# Using Galvanic Vestibular Stimulation to Sense Abstract Data

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**Abstract.** We propose using galvanic vestibular stimulation for presenting abstract data, for instance stock market trends. Using galvanic vestibular stimulation, data is felt directly as a perturbation in the sense of balance. This work is showcased as an art performance, where stock market fluctuations cause a person to maintain or lose balance. We present the artistic and technical principles underlying the performance and describe the technical implementation of a working system. The work shows how abstract data can be presented in a way that is not limited to visual, auditory, olfactory, or tactile sensing.

## 1 Introduction

The vestibular system senses linear and angular acceleration of the head and is the most significant sensory system for the maintenance of the sense of balance. Galvanic vestibular stimulation (GVS) refers to the process of applying small electric currents (approximately 1.0 mA) to the mastoid processes behind the ears, which stimulates the primary vestibular afferents of the inner ear [1]. When applied for a second or two, the current causes the subject to sway towards the stimulating anode. The effects of galvanic vestibular stimulation have been known since the early 1800s, but clinical and commercial use are still rare and GVS has only recently found popularity as a research tool. GVS methods have also been investigated for both the military and commercial use. A number of applications, including biomedical, entertainment, and pilot training, have been proposed [2].

GVS provides a data presentation technique that is not based on using visual, auditory, or tactile stimuli, to name a few of the most common sensory modalities used for inspecting data. Unlike traditional presentation modalities GVS causes immediate action, namely movement, when the subject receives an external vestibular stimulus. The current causes people to lose their balance and consequently to sway or fall either to the left or to the right involuntarily.

In this work we introduce a method for presenting and thereby sensing abstract digital information via vestibular stimulation techniques. We showcase the

work as a concrete art performance where stock market data affects the balance of the performer causing him to sway either to the left or to the right based on the stock market fluctuations.

## 2   Related Work

Most scientific research utilising GVS has focused on vestibular physiology and disorders of the vestibular system and use careful experimental settings in a laboratory environment. GVS is also suitable to be used as a human computer interaction (HCI) technique. For example, there have been attempts to use GVS in remote controlling people [3] and to enhance experiences of musical rhythms [4].

In a clinical setting, GVS has been investigated for use in rehabilitation after unilateral lesions caused by stroke. Improvement for patients suffering from visuo-spatial neglect [5] and impaired perception of verticality [6] have been reported. In addition, vestibular-evoked potentials have been used for diagnosis and monitoring the efficacy of treatment in various vestibular pathologies [7].

## 3   Performance

The artistic performance using GVS to convey stock market fluctuations took place in a shopping centre in Espoo, Finland, in April 2013 (see Figure 1 (a)). In the performance, GVS was used in order to have the performer experience changes in the stock market causing him to sway either to the left or to the right according to the movements of the market. The performance was organized on two consecutive days and lasted for 30 minutes each time.

For the performance, stock market data over a period of one week from OMX Helsinki was extracted from the web. In the performance this data was presented to the performer via GVS during a period of 30 minutes. The performer stood, eyes closed, on a dais while receiving stimulation from the GVS device. The stimulation was conducted via two electrodes attached behind the ears of the performer and connected to a GVS circuit board (see Figure 1 (b)). A wireless signal representing the direction of the stock market changes was sent to the board and accordingly an electric current was conducted with the anode on the left electrode if the stock market was going down or on the right electrode if the stock market was going up.

The galvanic vestibular stimulation caused the performer to lose his balance and to lean either to the left or to the right according to the side of the stimulation. The stock market changes were also projected on the wall behind the performer. The performances were attended by numerous people visiting the shopping centre and the event was recorded on video on both days [8].
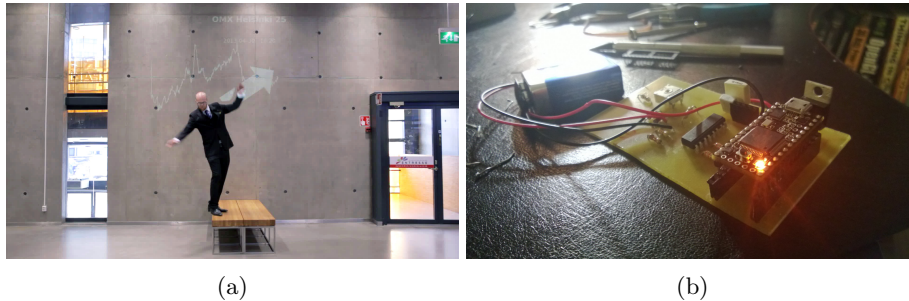
<center>(a)             (b)</center>

Fig. 1: (a) The GVS performance took place in the Entresse shopping centre in Espoo, Finland. (b) The printed circuit board of the GVS device complete with the RF receiver and the Teensy 3.0 microcontroller.

## 4 Prototype and Implementation

The setup consisted of a laptop with custom software and a GVS device. The laptop was used to parse the stock market data and feed it to the GVS device wirelessly over an RF transmitter-receiver link. The GVS device was a custom built printed circuit board (PCB) integrated into the suit jacket of the performer. The GVS PCB received the incoming stock market data and delivered the actual electric stimulation accordingly. The GVS PCB had four main components:

– An RF receiver for receiving the stock market data from the laptop
– A microcontroller for interpreting the data and controlling the stimulation
– An H-bridge for delivering the actual stimulation
– Two 9V batteries

The microcontroller used in the PCB was a Teensy 3.0. This microcontroller was selected due to its small form-factor and low power consumption which made it easy to integrate into the jacket. The RF transmitter-receiver link was a Seedstudio 433 MHz RF link kit. The kit provided wireless serial communication up to 10 m. The reception of the link was boosted by using an external antenna in both the transmitter and the receiver. The H-bridge used in the circuit was controlled by the microcontroller and it was used to change the polarity of a voltage applied over a load. The device was powered by two 9V batteries. One battery was used in conjunction with a 5V voltage regulator to provide power for the microcontroller and the RF receiver. The second 9V battery was used to power the H-bridge and provide electric stimulation.

Operating principle: The RF receiver passed the incoming information about the stock market data to the microcontroller. The microcontroller activated the H-bridge for 5 seconds. The polarity depended on the direction of the change in the stock market data. The H-bridge output had a potentiometer for manually adjusting the current running through the load. Before performance, the current was manually calibrated to the value where the effects of stimulation could be felt but no serious physical pain was induced.

## 5 Artistic Perspectives

Through the artistic performance we aimed to raise the question of how the external and intangible forces of society and economy affect us. Economic forces influence our lives in many ways, though often the effects are not obvious or they cannot be perceived directly. The abstract nature of the stock markets makes economic turns and causal relations hard to grasp. Our performance oversimplified this causality by making the effects absurdly concrete and raised questions and awareness of the economic and societal power the markets hold. Of course, the same methodology could be applied for presenting any other abstract data in a concrete way that directly affects the behaviour of the subject.

The performance was well received among the audience. Although the performance was arranged in the middle of a busy shopping center, people were interested enough to stay and follow the performance through. Many casual shoppers were enthusiastic when they understood the techniques used and were eager to discuss the themes and technology with us.

## 6 Conclusions and Future Work

We have proposed using galvanic vestibular stimulation to present abstract data in a way that directly affects the behaviour of the recipient. In the future work, we aim to extend methodology to different types of data, for example route or weather information.

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