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AN INTELLIGENT PLANT EMG SENSOR SYSTEM FOR PRE- DETECTION OF ENVIRONMENTAL HAZARDS

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Abstract: Environmental disasters are largely unpredictable and occur within very short span of time. Prior detection and warning of environmental disasters is more challenging and very important for survival. Plants are intelligent forms of life that are capable of providing pre-information about environmental hazards avoiding big catastrophe to human kind. Action potentials are a type of electrical signals from the plant that are transmitted along the cell membrane. The plant electrical signal is the reaction of plants to the stimulation or interfering with various conditions of environments. Communication from the plants can be achieved through modulation of the amplitude, frequency change, change in resistance and the rate of propagation of the electrical signal in the plant tissue. The aim of this research is to study and investigate plants response to environmental hazards such as landslides, earth quake, volcanoes or Tsunami etc, by receiving the signals generated from the plants in the nearby areas and to develop an intelligent wireless plant sensor network which can be used to predict the environmental hazards due to changes in the environment. However, as a first step, plant's response to landslides has been investigated in this paper. The experiments are conducted on the landslide setup to find the responses of the plants to the external stimulations are presented. It is found that the generation of electrical signals from the plant using electromyography sensors (EMG) during the beginning of the landslide gives pre-information which can be detected and communicated through wireless network to prevent the major loss.
Keywords: Plant EMG sensor system, Electromyography signals, landslide detection, Plant action potentials.

INTRODUCTION

Environmental disasters are largely unpredictable and occur within very short span of time. Prior detection and warning of environmental disasters is more challenging than other applications due to this very unpredictability of the occurrence (Maneesha, 2009). Therefore technology has to be developed to capture relevant signals with a minimum monitoring delay. Intelligent Wireless sensors investigated in this paper are one of the latest technologies that can quickly respond to rapid changes of data which can be sent to a data analysis centre from the remote hostile regions for further processing. Experiments have been made to detect the response of plants to external light conditions and used the same to run a bio-machine (Aditya et al., 2011). The fastest methods of long distance communication between the plant tissues

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and the organs are bio-electrochemical or electrophysiological signals. The effectiveness of such long-distance communication is clear, since plants can respond to external stimuli (e.g. changes in temperature or osmotic environment, illumination level, wounding, cutting, mechanical stimulation, or water availability) and changes can be detected in the plant soon after the injury (Ksenzhek and Volkov, 1998; Volkov and Haack, 1995). Recently researchers found that the transfer of volatile organic compounds (VOCs) signals between theplants (Baldwin et al., Feb.2006). The release of signal by the emitter plant and it transports, absorption, and perception by the receiver plant. The velocities of the propagation of electrical signals that have values from 0.5 mm to 4000 mm per second and are sufficiently high to facilitate rapid long-distance communication and these account for the rapid response phenomena observed in plants. The speed of propagation and the amplitude of action potential depend on the type of external stimulus that needs to be studied. So far no attempt has been made to use the plant intelligence for detecting environmental hazards. Here an attempt has been made on the preliminary study of the electromyography signals generated from the plants due to landslide phenomena. This will definitely lead to the development of an intelligent wireless sensor probe to detect the environmental hazards making it most cost effective method compared to other types of probes such as multi sensor deep earth probe (Maneesha, 2009).

STUDY OF PLANT SIGNALS

A. Type of Signals in the Plant

Scientific research indicates that plants communicate with insects, animals, human beings and other plants in order to keep themselves alive and safe. Any living cell continuously receives information from the environment. Two types of signals in the plant have been described: fast signals (Action potentials, APs) and slow signals (Variation potentials, VPs). A new type of electrical potential signals, called system potentials, has been postulated recently. The novel "system potentials" are detected in five different plant species, among them agricultural crops such as tobacco (Nicotianatabacum), maize (Zeamays), barley (Hordeum vulgare), and field bean (Vicia faba) (Fromm and Fei, 1998). Action potentials are an electrical waveform that is transmitted along the cell membrane characterized by a response (Volkov et al. 2004). Plant response to the environment change are its amplitude, frequency and intensity (Fromm and Lautner, 2007; Volkov and Brown, 2006). Thus, action potentials allow cells, tissues and organs to transmit electrical signals over short and long distances in plants. Variation potential propagate in the plant, as temporal changes in the depolarization and repolarization of the cell membrane; this kind of signal varies with the intensity of stimulation and appears to be associated with changes in tension or ion concentrations, creating a transient electrochemical unbalance in the xylem (Bose, 1926)

B. Importance of Wounding Plant Leaf

If a plant leaf is wounded, its action potential signal is stronger than that of unwounded leaf as shown in Figure 1 (Zimmermann et al., 2009). The strength of the inducing stimulus (wound signal) can influence the frequency when compared to that of systematic signal (unwounded signal).

MATERIALS REQUIREMENTS

A. Plant and Laboratory Conditions

Different kinds of plants such as cactus (Cactaceae), soya bean (Glycinemax), chrysanthemum (Dendranthema x grandiflorum) etc are used for the study. From all these plants a plant named croton (Codiaeum variegatum) has been selected for further research. It is observed that cactus does not respond much and there are no significant changes in the measured signal. Soybean and chrysanthemum generate weak signals and also the leaves of these plants are very thin and it is difficult to injure them. The leaves of the croton plant are thick compared to other plant leaves and are sensitive to external stimulation and hence selected for our experiments. However, experiments can be conducted for other types of deep-rooted plants and trees in actual fields. Experiments are conducted during morning, afternoon and evening and it is found that there is not much variation in the results since the experiments are conducted in open laboratory conditions with almost the same room temperatures. Figure 2, Shows Croton plant for measuring the action potentials using electromyography electrodes.

B. Selection of Electrodes

Electromyography (EMG) electrodes are generally used to detect the electrical potentials generated by muscle cells when these cells are electrically or neurologically activated. Two kinds of electrodes are used for detecting the signals coming from the plant. The first one is the Patch type EMG electrode and the other are conductive needle type electrodes. Uni Patch Tyco EMG electrodes, as shown in Figure 3 (a), are sensitive and circular in shape, with a diameter of 20 mm and are used to collect the output signal from the plant leaves. Another kind of electrode used is needle type conductive electrodes in as shown Figure 3 (b) and made of copper. The length of the electrode is 35 mm and the edge of the electrode is very sharp. The Surface area of the leaf is nearly 2600 mm^2 and the area of the electrode is nearly 314 mm^2. The ratio of leaf surface area to electrode area is nearly 8:1. Figure 2 shows the connection of these electrodes to the plant.

EXPERIMENTAL SET UP

Experimental testing is performed in different phases using the landslide laboratory setup (Maneesha, 2009). A landslide occurs when the balance between a hill's weight and the countering resistance forces is tipped in the favor of gravity. While the physics governing the

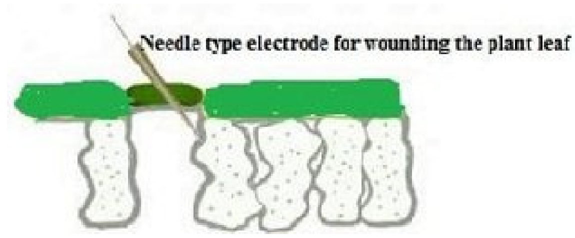

Figure 1. Insertion of electrodes through the stomata (Small pores; the leaf is in dark green color) into the inner tissue. Plant electrical signal behavior can be changed by this process.

Figure 2. Croton plant for measuring the action potentials.

(a) (b)

Figure 3. (a) Uni Tyco Patch type EMG electrodes and (b) Needle type conductive electrodes.

interplay between these competing forces is fairly well understood, prediction of landslides has been hindered thus far by the lack of field measurements over large temporal and spatial scales necessary to capture the inherent heterogeneity in landslide. Landslides may be fast moving, as in the case of mudslides, or relatively slow moving, causing fewer injuries. In either case, landslides pose considerable threats to man-made structures and can endanger human and animal lives. The advantages of plants or trees are of two types, First, planting flowers, shrubs or trees with extensive root systems can counteract the erosion caused by landslides. Secondly, they can act as an intelligent information system for the predetection of landslides by tapping the electromyography signals or action potentials through a wireless sensor device.

A. Landslide Laboratory Setup

Two landslide laboratory setups, a large and a medium scale, are used for the experiment to better understanding the behavior of the plants (Maneesha, 2009) in a landslide scenario. This will aid in detecting and predicting landslides before conducting similar experiments in the field environment.

Figure 4. Landslide experimental setups: Left-medium scale, Right-large scale

Figure 5. Experimental landslide setup showing the tilt variability

Two landslide laboratory setups, a large and a medium scale, are used for the experiment to better understanding the behavior of the plants (Maneesha, 2009) in a landslide scenario. This will aid in detecting and predicting landslides before conducting similar experiments in the field environment. These two laboratory setups have been used for modeling and simulating the landslide phenomena. The medium-scale laboratory setup and the large-scale laboratory setup are shown in Figure 4. These laboratory setups are equipped with indigenously designed and developed seepage simulators and rainfall simulators to generate the required water infiltration.

B. Modes of Testing

Two modes of testing are carried out, one for static slopes in which seepage and rainfall flow is added, and the second for relatively static hydrology conditions. A variable tilt can be used in these laboratory setups as shown in Figure 5. The large and medium laboratory setups can be used to determine different critical parameters such as the time of slope failure, rate of seepage or rainfall rate that induces the slope failure, the slope angle that triggers the slope instability for a constant seepage or rainfall rate, the remaining time duration before the slope instability may arise, the threshold values of each of the geophysical sensors, the effects of homogeneous or heterogeneous soil structure, the effect of soil properties, the effect of vegetation, and the effect of toe removal, etc,. The laboratory set up experimentation can replicate the real life conditions providing the potential future results of the landslide scenario.

RESULTS AND DISCUSSIONS

The landslide setups, as explained earlier, are used to study the signals coming from the plant in response to landslide stimulations due to two modes of testing. Measurable changes in the bio-electromyographic activity of the plants and their emissions are recorded using

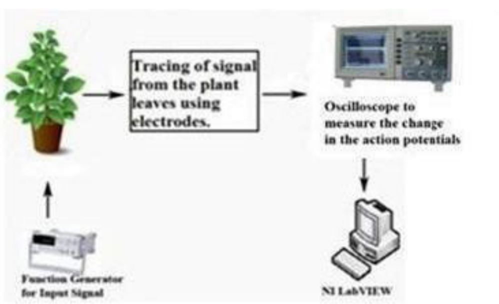

Figure 6. Hierarchy of the data acquisition System

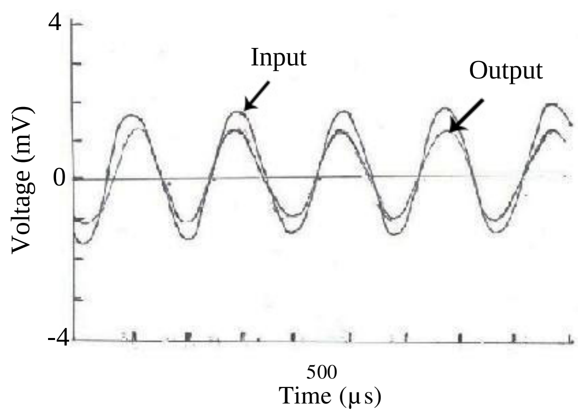

Figure 7. Change in output signal from the plant with constant sinusoidal input signal

oscilloscopes. Normally the energy of plants fluctuates most strongly during the day. During the early stages of a landslide i.e., when the landslide force is greater than the resistive force, the energy field of the plant gets increased due to the external force acting on the plant. This generates the action potential signals from the plant, which can be communicated through a wireless sensor networks to the remote station for further processing. Based on this intelligent information, pre-detection and early warning can be issued to avoid major loss due to landslide making it most cost effective method compared to other type of multi-probe sensors. The output signals from the plant are recorded using a digital oscilloscope. These observations are also made by giving an input signal to the plant using a function generator.

A. Static Slope Testing and Observations

During static slope testing, the landslide setup is kept at a constant slope but seepage and rainfall flow is added and the effects of the landslide on the plant electromyography signals are recorded using a digital oscilloscope. Totally, two electromyography (EMG) electrodes and one needle type conductive electrode are used for the experiment. The sinusoidal input signal from the function generator is passed through the needle type electrode to the plant.

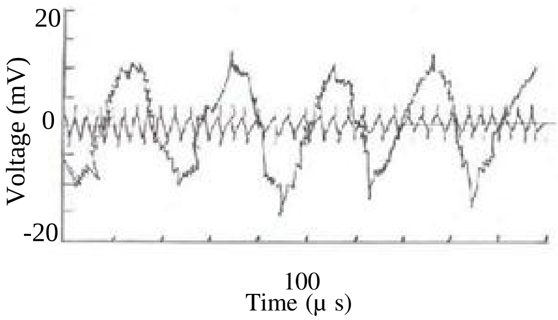

Figure 8. The two output signals from the the plant at different periods of time during static slope testing without sinusoidal input signal.

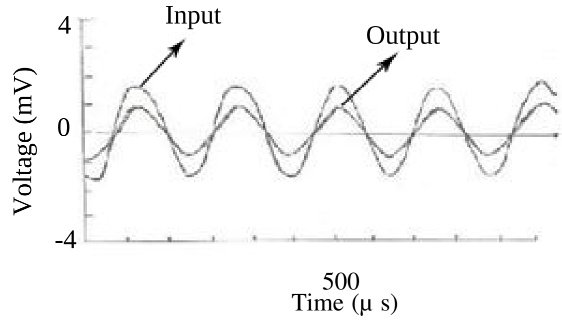

Figure 9. Change in output signal from the plant with constant sinusoidal input signal at the beginning of the sliding of sand particles on the surface of the inclined slope.

The output signal is collected through an EMG electrode for detecting the action potential signals from the plant. The other EMG electrode is used as a reference electrode connected to the leaf. The frequency of the function generator is chosen based on the action potential signal strength coming from the plant leaf. The experiments are carried out with different frequencies, ranging from 15 KHz to 30 KHz. The output from the EMG electrode is connected to the oscilloscope. The analog output signal is viewed in the screen and the same is converted to digital data. NI LabVIEW is used for analyzing the signals coming from the plant as shown in Figure 6.

When the sinusoidal signal frequency from the function generator is at 20 KHz, the output signal from the plant has the same nature as that of the input signal but with little variation in amplitude as shown in Figure 7. The amplitude of the output signal varies as the intensity of landslide or the sliding force increases. Figure 7 shows the output signal when the water content in the soil is maximum and the sand particles are just starting to slip down the slope. This may be taken as the pre-indication of the beginning of the landslide. The amplitude of the output signal increases to a particular level for a certain period of time after which there is no significant increase in the amplitude. This may be due to loosening of the sand at the roots of the plant and the external stimulations becoming stronger as the landslide takes place. This clearly shows the response of the plant due to the landslide force acting on the plant roots causing the generation of action potential or electromyography signals. If the plant is exposed to the above phenomena directly without the sinusoidal input signal as shown in Figure 8, similar results are obtained except that the action potential signals are combined with the noise. Better output electrodes may be used to avoid noise in the signal. As shown in the Figure 8, the lower amplitude signal represents the initial signal when the sand is almost dry or little wet condition. As the rainfall flow is added gradually, the sand particles become loose and started sliding down the slope causing increase in the signal amplitude as shown by the large amplitude signal. This gives the clear indication of beginning of the landslide due to increase in water content in the soil. The change in the response signal directly from the plant is more evident compared to the sinusoidal signal variation with the input from the function generator as shown in Figure 7.

B. Variable Slope Testing and Observations

In this case, the hydrology conditions of water in the soil are kept constant and the tilt of the setup is slowly varied to cause the landslide to happen. Figure 9 shows the sinusoidal input signal and the corresponding output action potential signal from the plant at the beginning of the sliding of the sand particles on the surface of the inclined slope. Figure 10 shows the two output signals, one at the beginning of the tilting of the setup. That is approximately at the

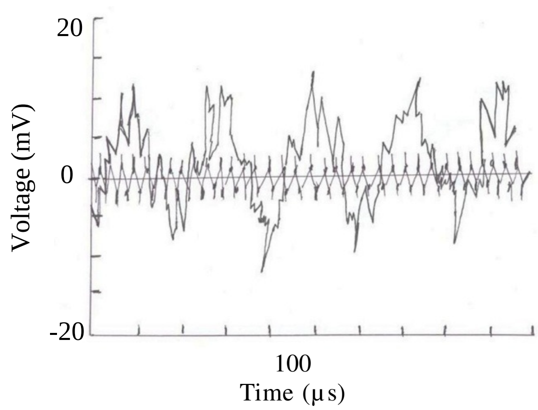

Figure 10: The two output signals from the plant at different points of time during variable slope testing without sinusoidal input signal

horizontal position of the landslide setup. The setup is slowly tilted using the motorized mechanism. As the tilting angle increases, there is a change in the amplitude of output signal up to a certain period beyond which there is no significant change in the signal amplitude.

This may be due to the sand particles adhering to the plant roots got loosened due to the landslide and there is no external stimulation or force causing the change in signal amplitude. The higher amplitude signal shown in Figure. 10 is just at the beginning of the sliding of sand particles down the inclined surface.

As mentioned earlier, some noise is present in the show that the field implementation of an electromyography based wireless sensor device for the pre-detection of a landslide is possible. This innovative technique is cost effective and can be implemented effectively on a larger scale.

CONCLUSION

In this research a simple method of detecting plant signals is investigated and the method is verified experimentally for the pre-detection of landslides. Experiments are conducted in the laboratory landslides setups and the experimental results prove that it is possible to build an intelligent wireless sensor device based on the plants electromyography or action potential signals generated due to the external stimuli. Thus plants act as an intelligent sensor to external stimulations. A wireless sensor network based on this technique can be implemented for real-time monitoring of areas that are prone to disasters. This work provides additional insight into the design, development, and deployment of a low-cost wireless sensor network for landslide detection in the field application.

The present work has paved the way for extensive research on plant intelligence in response to external stimuli as it demonstrates the true potential for innumerable and very interesting applications. Green plants interfaced with a computer through data acquisition systems can be used as biosensors for monitoring the environment and to detect the effects of pollutants on the plants. This method can also be used for the study of plant electrophysiology. Future studies will also be directed towards a better understanding of the plant action potential signals and its response to the other environmental conditions such as the weather, and the presence of sunlight, temperature, pesticides, etc. Using this efficient technique, it may be possible to pre-detect other environmental hazards such as earthquake, volcanoes and tsunamis by monitoring the signals from plants. This investigation demonstrates significant advantages in using this technique for building a wireless sensor network for disaster management as compared to the conventional techniques of using multi-sensor probes. Further work is needed in conducting experiments in deep-rooted plants and trees for efficient detection and monitoring of environmental hazards. Animals also promise to be strong candidates for disaster pre-warning, as shown by the well-documented abnormal behaviour of animals before major natural disasters, such as tsunamis, earthquakes, and landslides.

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