Seismic Survey with Drone-Mounted Geophones

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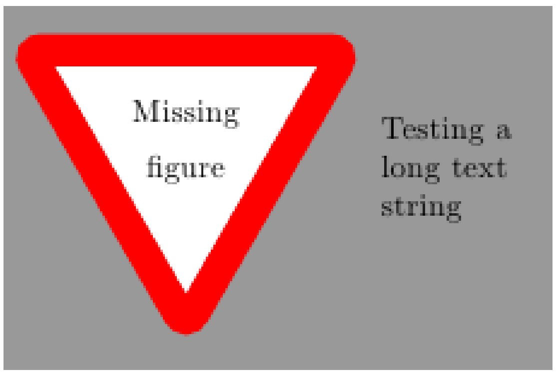

Fig. 1: insert Figure 1

***Abstract*—Seismic imaging is one of the major techniques (and industries in Texas) for subsurface exploration and involves generating a vibration which propagates into the ground, echoes, and is then recorded using motion sensors. There are numerous sites of resource or rescue interest that may be difficult or hazardous to access. In addition, there is often many places to survey, which require a great deal of hand labor. Thus, there is a substantial need for unmanned sensors that can be deployed by air and potentially in large numbers. This paper presents working prototypes of an Autonomous Flying Vibration Sensor that can fly to a site, land, then listen for echoes and vibrations, transmit the information, and subsequently return to its home base. One design uses four geophone sensors (with spikes) in place of the landing gear. This provides a stable landing attitude, redundancy in sensing, and ensures the geophones are oriented perpendicular to the ground. The paper describes hardware experiments demonstrating the efficacy of this technique and comparing with traditional manual techniques.**

Keywords*—Data Acquisition, Geophones, Quadcopters, Seismic Exploration

I. Introduction

Hydrocarbons (coal, oil, natural gas) are estimated to supply more that 66% of the total energy consumed on earth during the year 2014 by IEA (International Energy Agency)

add this to references

. Thus hydrocarbon exploration, the search for hydrocarbons (oil and natural gas deposits) below the earth?s surface or sea bed is essential to sustain life on this planet. Millions of dollars are pumped into exploration since these hydrocarbons are major sources of energy, to avoid hazards (maintain safety) as they are inflammable and are an essential part of the socio-economic development.

Traditional exploration involves planting geophones (sensors) into the soil and detecting seismic disturbances caused from a *Veibroseis* trucks (trucks with a heavy metal plate) or dynamite act as the source of vibration, as these vibrations propagate on the surface they are detected by the geophones and the data is stored. The data obtained describes the intensity of the pressure wave generated by the source over a time period and is received by the geophones (sensor). This data is highly useful in analyzing the underground rock structure and inferring the presence of hydrocarbons. Hence instead of randomly searching for hydrocarbons the exploration is carried out by using state of the art techniques, equipment and skilled labor over a large area with potential hydrocarbon reserves. An array of sensors are placed in different patterns while the test is performed, these geophones have a spike and are pushed into to ground to aid the sensing process. Coupling between the sensor and ground is at most important while testing. Since the sensor is coupled with the ground, when the source generates pressure waves the ground oscillates these oscillations are sensed by the sensor and the data is transmitted to the seismic recorder and stored.

The current state of the art technology used to perform exploration is bulky and has long cable connections connecting an array of geophones to the seismic recorder. This requires a lot of manual labor, transportation resources, time and energy. These explorations are carried out on thousands of square kilometers of area multiple times. There are emerging technologies that can improve the situation, there are autonomous sensor systems which have spikes and have to be pushed into the ground but instead of an array of sensors which are connected in series to the seismic recorder in general using bulky cable wires, the autonomous node is a single unit comprising the sensor and seismic recorder and battery. It can be deployed at a location for days and collect data, but this data can be viewed only after the experiments are over this is the same case with the extensively used cabled system. This is a drawback since if the data collected was faulty (bad coupling of geophone, the node can be stolen) we would not know until the experiment is over. A recent breakthrough is to wireless sensor nodes and real time data acquisition systems. This improves the system tremendously and using wireless transmission (Radio Frequency) we can cut short the transportation and use of bulky cables. It helps in analyzing complex terrains with mountains, rivers which could not be achieved with the cable system. Real time data acquisition is useful in detecting faults and instant analysis is useful to plan future operations. This system has overcome most of the drawbacks from the cabled systems but this still requires manual labor for setting up their hardware and removing it. The hardware has to be moved periodically during the exploration process to cover the complete field area which again requires manual work.

The solution is simple, we need to automate the complete process. Quadcopters (flying robots) are extensively used in pick and drop tasks, these robots are gaining incredible popularity amongst the research fraternity and as a commercial product for recreation and delivery tasks. Quadcopters can be the solution the missing piece in the puzzle to automate the process of seismic exploration. Instead of having humans deploy the sensor nodes quadcopters can deploy, retrieve and recharge these sensor nodes by magnetic induction using on board sensors sensors (Camera, lasers, IR) and GPS information. A swarm of robots can perform the task efficiently thereby saving time, resources and decrease the possibility of errors. The major task is to ensure coupling with the surface, which is essential in obtaining quality data. [3], [1], [2]

II. Overview and Related Work

A. Traditional Seismic Exploration Methods

cite the book that Li sent us. Also cite some papers by Rob.

an equation describing seismic waves in earth

a) Cabled Systems

b) Wireless systems

c) Mobile robot

mention the patent here

B. Wireless Sensor Networks with Drones

cite some recent robotics papers on drone sensor networks

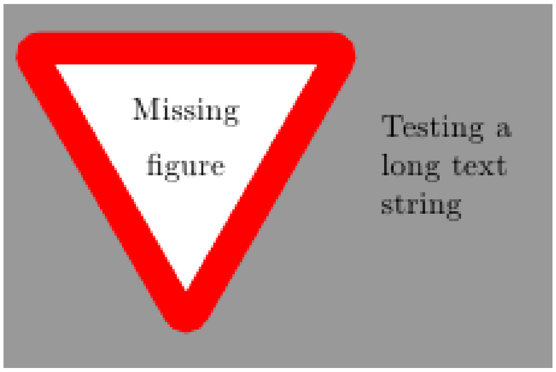

Fig. 2: Figure showing the seismic drone, with labels on each part

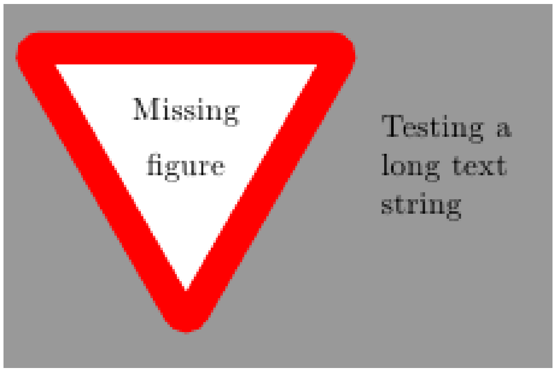

Fig. 3: System setup for comparison with traditional geophone system.

III. Experiments

Three experiments were completed

A. Comparison with traditional geophone system

The seismic drone lifted off, flew to the same locations as four cabled geophones, and was coupled to the recording equipment.

B. Recording seismic disturbance using onboard GSR

To ensure all measurements had the same attenuation and were synchronous, the previous test connected the seismic drone to a cabled system. This experiment demonstrates that the onboard GSR records seismic disturbances.

C. Wireless transmission of seismic disturbances

describe the Arduino blue-tooth solution

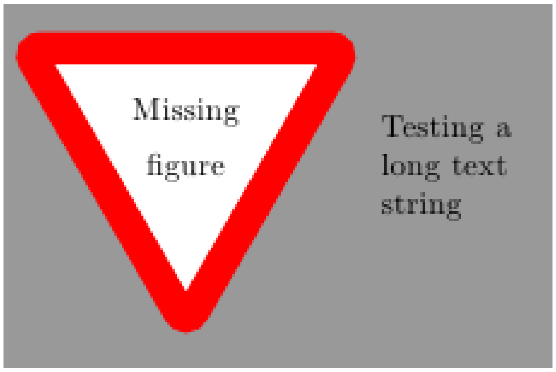

Fig. 4: 2 plots showing comparison with traditional geophone system for (1) hard surface, and (2) dirt surface

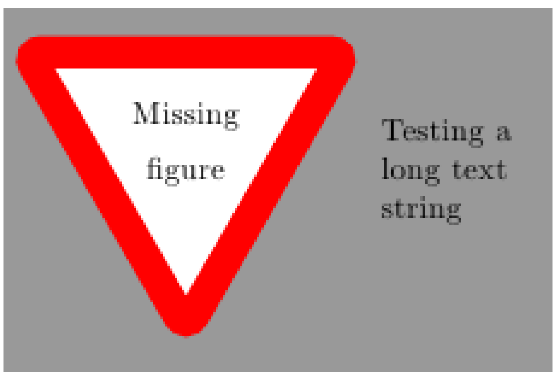

Fig. 5: Data recorded by the cable-free seismic drone

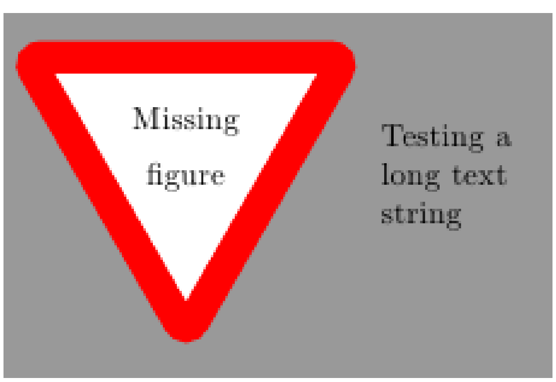

Fig. 6: One plot from the Arduino blue-tooth equipped quad copter.

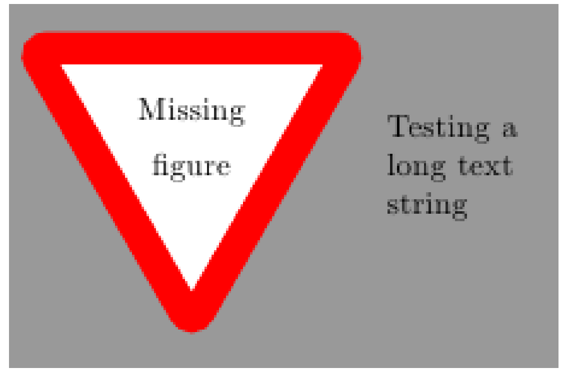

Fig. 7: The seismic drone was commanded to land at the location marked with a green 'x'. The actual positions are shown with blue 'o'. The mean and ± 1 standard deviation ellipses are drawn in red.

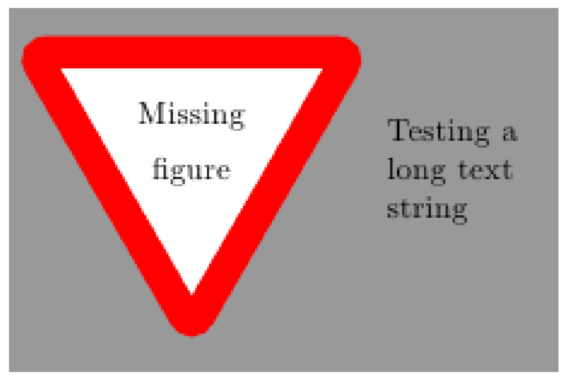

Fig. 8: (left) Photographs of seismic drone geophone feet in different soils, with a ruler visible. (right) plot of penetration depth for three different soil types.

D. Accuracy of autonomous landing with geophone setup

Seismic exploration depends on accurate placement of geophones over a large geographic area. This experiment tested the accuracy of autonomous landing of the fully loaded The seismic drone was

E. Coupling in various soils

IV. Conclusion

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