Seismic Survey with Drone-Mounted Geophones

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***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. [**?**] Millions of dollars are pumped into exploration since these hydrocarbons are major sources of energy, it is essential for sustaining life and socio-economic developments. Avoiding hazards and maintaining safety is necessary as they are highly-inflammable and human life is at stake thus essentially requiring state of the art equipment to prevent disasters.

Traditional exploration involves planting geophones (sensors) into the soil and detecting seismic disturbances caused from Veibroseis trucks or dynamites which act as a 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 period of time. This data is critical and is used in analyzing the underground rock structure and inferring the presence of hydrocarbons. Instead of randomly searching for hydrocarbons, explorations are carried out using elaborate technical procedures, equipment and skilled labor over a large area there by increasing the possibility of discovering hydrocarbon-reserves in an optimal fashion. Even though traditional exploration methods are extensively used they are not in par with the current advancements. The use of cables to connect the microprocessor and the senors leads to drawbacks like increase in overall cost, inaccessibility in certain terrains. The exploration process involves deployment and redeployment of sensors repeatedly manually. With current advancements in automation, automating the process would reduce the expenditure and increase precision. Drones or unmanned aerial vehicles (UAVs) are flying platforms with propulsion, positioning, and independent selfcontrol. As drone technology improves and regulations are adopted, there are major opportunities for their use in scientific measurement, engineering studies, and education. In particular, measuring mechanical vibrations is a key component of many fields,

Fig. 1: Fig. 1, Comparing manual and robotic geophone placement. 1a.) Currently, geophones are planted manually [1]. 1b.) Traditional methods require extensive cables to connect geophones to the seismic recorders and batteries. Shown are wire bundles lined up for transportation from the exploration site [2]. 1c.) The Seismic Drone in this paper is an autonomous unit requiring no external cables. This paper presents an automated process of sensor deployment and retrieval.

including earthquake monitoring, geotechnical engineering, and seismic surveying. 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 might be 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. We have built 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. The goal of this paper is to design, build, and demonstrate the use of motion sensing drones for seismic surveys, earthquake monitoring, and remote material testing. (??) gives a description of current state of the technology available in the industry and why Seismic Drone is better. Followed by the (??) that describes the hardware experiments performed. (??) discusses the performance of the above system with traditional methods and followed by (??) Conclusion .

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

III.Experiments

Three experiments were completed

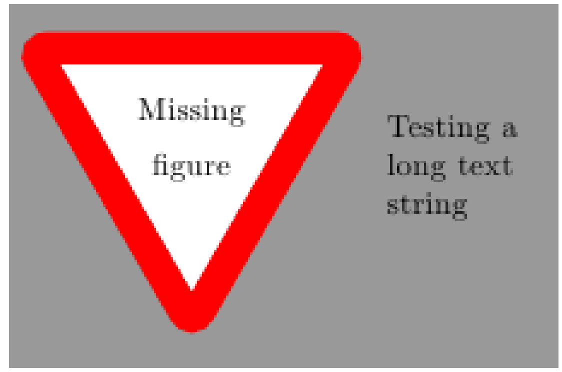

Fig. 2: Figure showing the seismic drone, with labels on each part

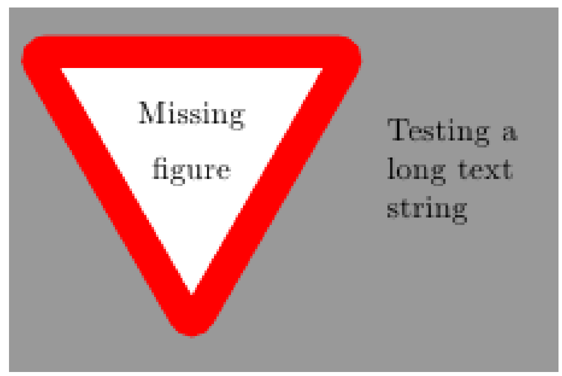

Fig. 3: System setup for comparison with traditional geophone system.

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

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

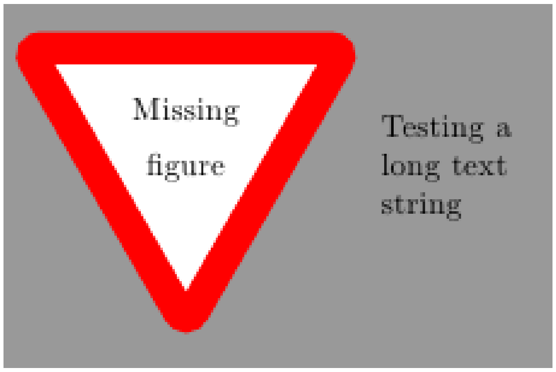

Fig. 4: 2 plots showing comparison with traditional geophone system for (1) hard surface, and (2) dirt surface

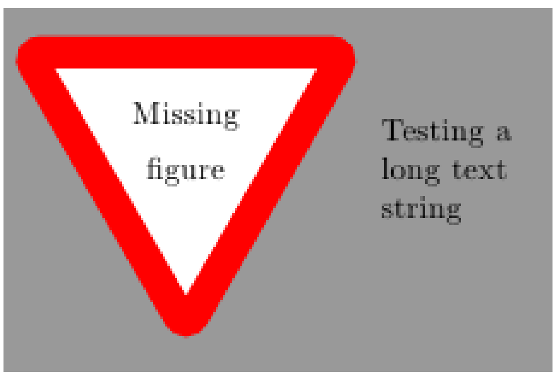

Fig. 5: Data recorded by the cable-free seismic drone

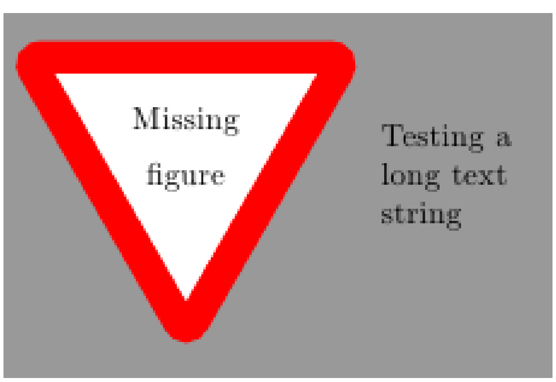

Fig. 6: One plot from the Arduino blue-tooth equipped quad copter.

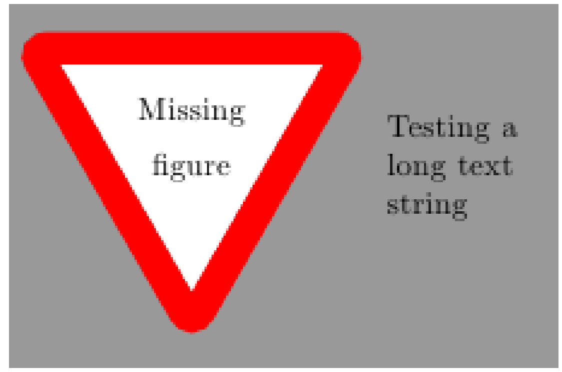

Fig. 7: The seismic drone was commanded to land at the location marked with a green 'x'. The actual positions are shown with blue 'o'. The mean and ± 1 standard deviation ellipses are drawn in red.

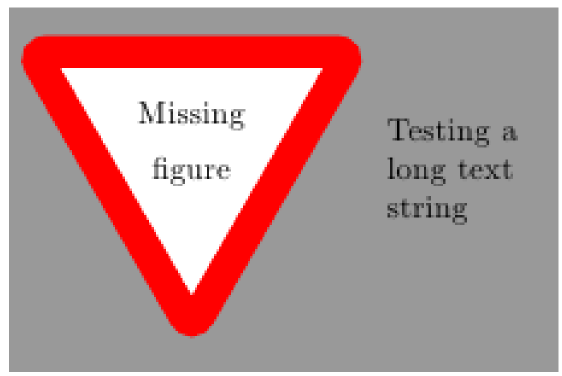

Fig. 8: (left) Photographs of seismic drone geophone feet in different soils, with a ruler visible. (right) plot of penetration depth for three different soil types.

E. Coupling in various soils

IV. Conclusion

References

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