Large-Scale Seismic Sensing by a Heterogeneous Robotic Team

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***Abstract*— Seismic surveying requires placing a large number of sensors (geophones) in a large grid pattern, triggering a seismic event, and recording accelerometer readings at each sensor. These readings are inverted to infer the location of hydrocarbons. Traditional seismic surveying employs human laborers for sensor placement and retrieval. Use of explosives, harsh climatic conditions, high costs and time associated with human deployment are the major drawbacks of traditional surveying. We propose an autonomous heterogeneous sensor deployment system using drones to plant and recover sensors. Detailed analysis and comparison with tradition surveying were conducted. Hardware experiments and simulations prove the effectiveness of automation in terms of cost and time. The proposed system overcomes the drawbacks and displayed higher efficiency.**

I. Introduction

Seismic surveying is a geophysical technique involving sensor data collection and signal processing. It aims at identifying and retrieving hydrocarbons like coal, petrol, natural gas. Traditional seismic surveying involves manual laborers placing geophone sensors at specific locations connected by cables. Cables are bulky and the amount required is directly proportional to the area surveyed. On average hundreds of square kilometers must be surveyed, requiring many kilometers of cabling. Remote locations often require seismic surveying, with concomitant problems of inaccessibility, harsh conditions, and transportation of bulky cables and sensors. These factors increases the cost.

Nodal sensors are a relatively new development to the seismic sensing. Nodal sensors are autonomous units that do not require bulky cabling. They have an internal seismic recorder, a micro-controller that records seismic readings from a high-precision accelerometer. Because this technology does not require cabling, the overall cost is reduced. Currently nodal sensors are becoming popular in the USA due to reduced costs in seismic sensing. However, these sensors are still planted and recovered by hand. This paper introduces an automated technology for planting and recovering wireless sensors. The technology presented may have wide applicability for quickly deploying sensor assets for geoscience, earthquake monitoring, defense, and wildlife monitoring.

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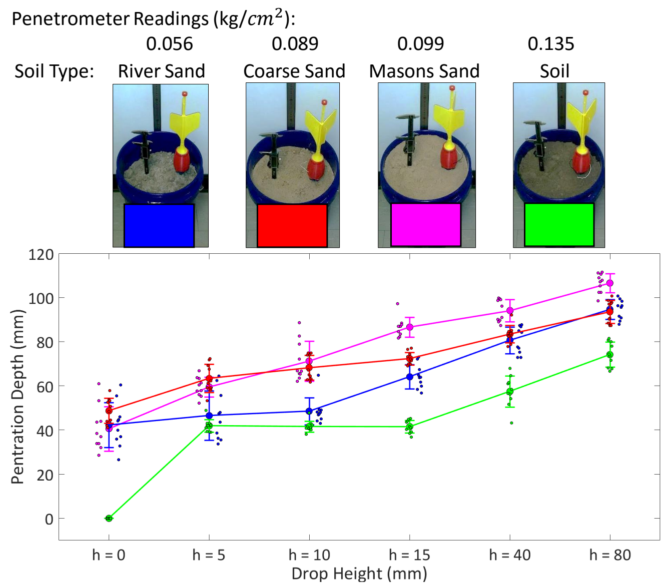

Fig. 1: Drop height vs. penetration depth in four soil types.

II. Overview and Related Work

A. Seismic Sensing

B. Sensor networks

C. Multi-Robot Assignment

III. Smart Darts

A. Design

B. Experiments

1) Exp 1: Drop tests in different soils

Drop tests as function of soil type, depth and angle

2) Exp 2: Straight vs Bent Fins

Drop tests as function of height. Compares depth and angle for twisted vs. straight tail.

3) Exp 3: Autonomous drop

Exp 3: Automatic drop from drone, accuracy in placement

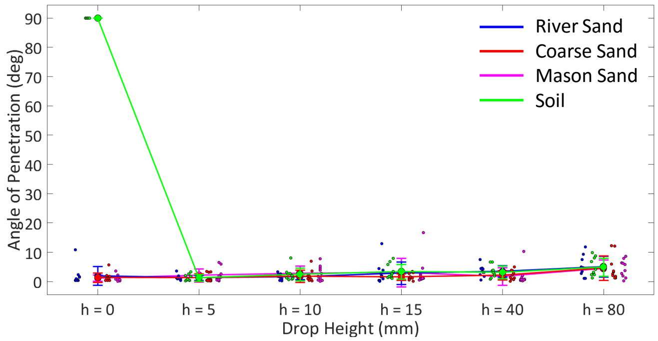

Fig. 2: Drop height vs. angle of deviation in four soil types.

Fig. 3: Outdoor Drop test comparing Straight vs Bent fins performance. a.) smart dart dropping b.) measuring drop height

4) **Exp 4: Shot gather comparison**

Exp 4: Dart sensing accuracy vs ground setup

IV. SeismicSpider

A. Design

B. Experiments

1) **Exp 1: Accuracy plot**

Hexapod move to desired GPS location (plot accuracy)

2) **Exp 2: Shot gather comparison**

Hexapod sensing accuracy vs ground setup

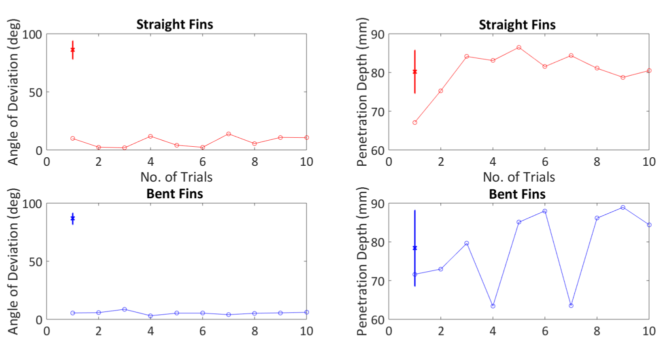

Fig. 4: Straight vs Bent fins comparing penetration depth and angle of deviation. Experiment used a fixed drop height of 9.8 m.

3) **Exp 3: Deploying and Retrieving Hexapod**

Exp 5: Retrieving Hexapod

V. DeploymentUnit(UAV)

A. Design

B. Experiments

VI. Comparision

VII. Conclusion and FutureWork