Sensor Network for Landslide Detection

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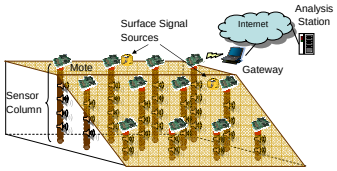
Problem Statement

- A landslide is an event where a block of earthen mass slides downhill covering the area underneath with dirt and debris.
- Landslides are a major geologic hazard in the U.S.
  - 25 to 50 fatalities per year
  - $1B to $3B property damages
- Fundamentally **spatially and temporally distributed process** over **highly heterogeneous environment**

Research Questions

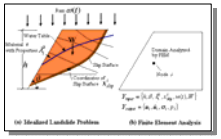
- Number and location of seismic sources to achieve necessary localization accuracy
- Sensor column density necessary to correctly estimate Y_{input}
- Number of sensors per column necessary to accurately estimate location of slip surface
- Calibration algorithms to compensate for changes in signal propagation speed due to environmental changes (e.g. rain)
- Effect of soil heterogeneity on the accuracy of displacement calculations

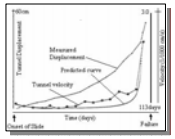
Sensor Network



- **Sensor columns** detect changes in their relative locations
- Collaborate to estimate location of ***slip surface***
- Transfer measurements to analysis station
- Collected measurements are used to drive the **Finite Element Model**
- Analysis gateway can request additional measurements

Landslide Prediction Algorithm

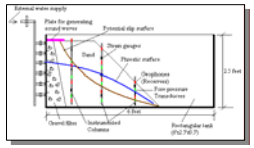




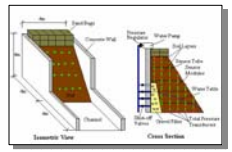
- Goal: Calculate displacements $u_i(t)$
- If Y_{input} is known Y_{output} can be calculated via Finite Element Model
- Use Y_{output} collected from sensors to back calculate unknown parameters of Y_{input}

Testbeds

- Small-Size Testbed
  - 2-dimensional sand tank
  - Testbed for the FEM Model

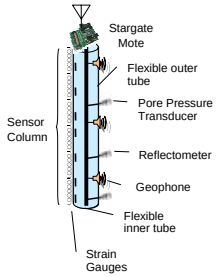


- Medium-Size Testbed
  - Artificial Hill
  - Testbed for signal processing algorithms, three-dimensional landslides



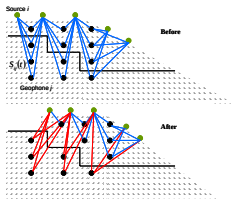
Sensor Column

- **Stargate** Gateway
  - Powered by battery + photo cell
- Connected to peripherals placed at different lengths of a flexible tube
  - **Geophones**
    - Measure distance from seismic signal sources
  - **Pore Pressure Transducer & Reflectometer**
    - Measure positive and negative pressures and moisture content
  - **Strain Gauges**
    - Detect tube deformation
    - Other sensors are powered off until triggered by Strain Gauge → Save Energy
- Gateway is above ground rest of the column is below ground



Distributed Signal Processing

- Estimate initial set $S_{ij}(t)$ of distances between Source i and geophone j
- Calculate new set $S_{ij}(t+\Delta)$ after movement
- Use **belief propagation** to determine sensors that moved
- Use **tri-lateration** variant to estimate new sensor locations
- Estimate location of slip surface from set of sensors that moved



Current Status and Future Steps

- Current Status
  - Preliminary implementation of signal processing algorithms completed
  - Small-scale testbed is being built for generation of realistic simulation input
- Next Steps
  - Build sensor column hardware
  - Deploy medium-scale testbed
  - Test algorithms on medium-scale testbed

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