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., with 25 to 50 fatalities per year and $1B to $3B property damages. Fundamentally, spatially and temporally distributed processes occur over highly heterogeneous environments.

Landslide Prediction Algorithm

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

Distributed Signal Processing

- Estimate initial set \( S_i(t) \) of distances between Source \( i \) and geophone \( j \)
- Calculate new set \( S_i(t + \Delta t) \) after movement
- Use belief propagation to determine sensors that moved
- Use trilateration variant to estimate new sensor locations
- Estimate location of slip surface from set of sensors that moved

Sensor Network for Landslide Detection

- 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

Testbeds

- Small-Sized Testbed
  - 2-dimensional sand tank
  - Testbed for FEM Model
- Medium-Sized Testbed
  - Artificial hill
  - Testbed for signal processing algorithms, three-dimensional landslides

Research Questions

- Number and location of seismic sources to achieve necessary localization accuracy
- Sensor column density necessary to correctly estimate \( Y_{\text{output}} \)
- 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

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