USDA Summer Intern Meeting: Opening Presentation

Jose Andres Cortes

Department of Mathematics
University of Texas at Arlington

In collaboration with: Dr. Korzeniowski, Dr. Tolbert, Dr. Galina, Dr. Kravetski (USDA-ARS)

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Outline

Outline

Meet the Team

- Dr. Korzeniowski (UTA)
- Dr. Tolbert (USDA-ARS)
- Dr. Galina (USDA-ARS)
- Dr. Kravetski (USDA-ARS)

We are working on the MINS project, using gamma spectroscopy to measure soil carbon content in the field.

The MINS Project

This is the machine we're working on. This is me next to the machine during my visit to the lab in Auburn, Alabama. The machine is called **MINS** *(Mobile In Situ Spectroscopy).*

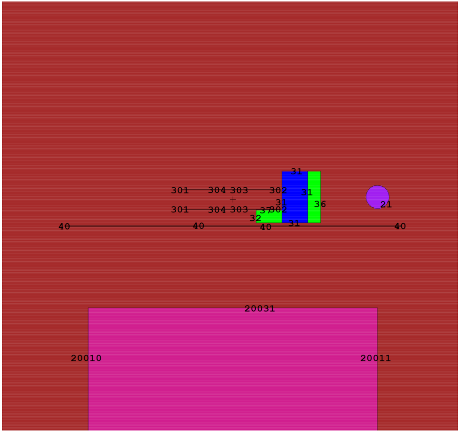
Outline

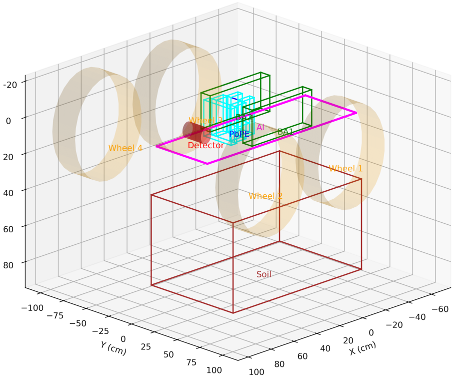
Project Development

- USDA develops and tests the physical MINS machine.
- **My role:** Mathematical and statistical support.
- Two main focus areas:
  - Simulation
  - Data Analysis

Outline

Simulation

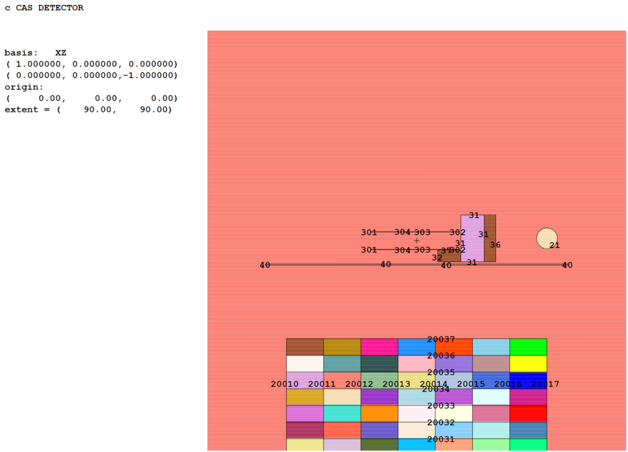




- Simulate MINS using Monte Carlo particle methods (MCNP).
- Predict machine performance in various scenarios.

We use the national code MCNP to simulate the MINS results and predict the performance of the machine in different scenarios.

Recent Work in Simulation



Recent work: Introduced functionalized soil samples. Previously, samples were simulated as chemically even; now, we simulate them as digitized functions of spatial dimensions for more realistic data.

Outline

Analysis

Leading Analysis Method

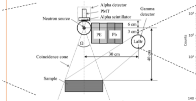


Figure G – MINS Architecture

The **MINS system** utilizes a neutron generator to emit fast neutrons ($10^9 n$/sample), which interact with carbon nuclei in the soil. The **INS** events produce gamma radiation signatures that are captured by energy detectors. Analysis is done on the **Recorded Spectrums**

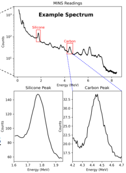


Figure H – Simulated MINS Readings

Method 1: Peak Fitting (PF)

The sum of a **peak function** and **baseline function** are fit onto the true spectrum.

Gauss Peak Function: (Caused by **INS**)

$$f(x) = a\exp\left(-\frac{(x-b)^2}{2c^2}\right)$$

Baseline Function:

linear:

$$f(x) = ax + b$$

exponential falloff:

$$N(t) = N_0 e^{-\lambda t}$$

(Caused by **other**)

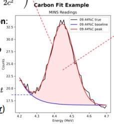
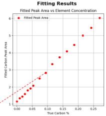


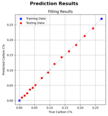
Figure I – Peak Fitting



Figures J – C% vs Peak Areas

Fitting is done with the least-squares method

The **peak areas** are correlated to the carbon content of the soil. The outermost values are used as the training data for linear regression in a final prediction:



Figures K – True C% vs Predicted C%

Mean Squared Error: 7.56223e-06

Other Analysis Methods

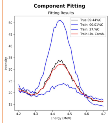


Figure L – Simulated MINS Readings

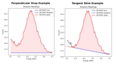
Method 2: Component Fitting (CF)

The tested spectrums are treated as a linear-combination of training spectrums. The coefficients of the fit are multiplied by the elemental concentrations

$$spec_{true} = \Sigma(w_i * spec_i)$$

$$c\%_{true} = \Sigma(w_i * c\%_i)$$

Classical Methods:



Figures M – Classic Methods

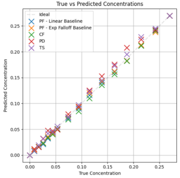
Perpendicular Drop (PD) The minimum of the element window is taken as the baseline

Tangent Skim (TS) The baseline is the Tangent of the minimums of both peak valleys

Results

The MINS System is very effective at measuring carbon in simulated environments. **Peak fitting with a linear baseline** being the most effective method under simulated conditions.

Future Work includes testing to see how the error for the methods changes depending on the number of particles that are emitted from the neutron source, as well as under more complex soil conditions.



Figures N – Prediction

Spectrum Analysis Method	MSE
Peak Fitting – Linear Baseline	6.00647e-06
Peak Fitting – Exponential Baseline	7.56223e-06
Component Fitting	1.89773e-05
Perpendicular Drop	0.00741817
Tangent Skim	0.00504626

Second area: Analysis of the data obtained from MINS. Last year, I focused on analysis methods for the spectrum recorded by the machine.

Outline

Goals for This Summer

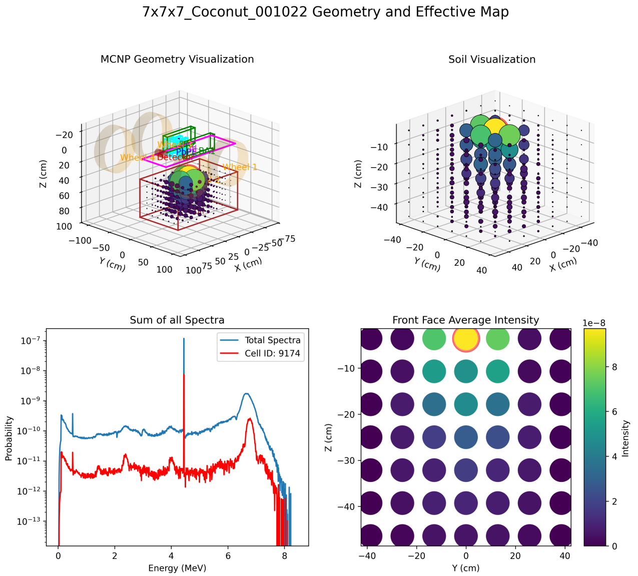
1. Develop and evaluate mathematical methods for new machine architecture.
2. Detection Range (Depth) study of the MINS machine.
3. Comparison of MINS and soil core measurements.
4. Mapping the results of the machine onto a field.
5. Estimation of the impact of the surface area sampled on field measurements.

Overall, these goals are about mathematically testing the capability of the machine.

Project Steps

1. Generate Pure Spectrums (Spectrum Generation)
2. Generate Effective Map (Associative Map)
3. Try Fast Spectrum Convolution (Spectrum Generation)
4. Compare Analysis Methods (Apply previous code to new data)
5. Variance Study
6. Depth Study
7. Core Harvesting Comparison (local)
8. Mapping Comparison
9. Field Coverage Study

First Steps Completed



Questions?

Any questions, comments, concerns?

Thank you!