Comparison Between Electrical Impedance and Optical Spectroscopy for a Field Soil Analysis

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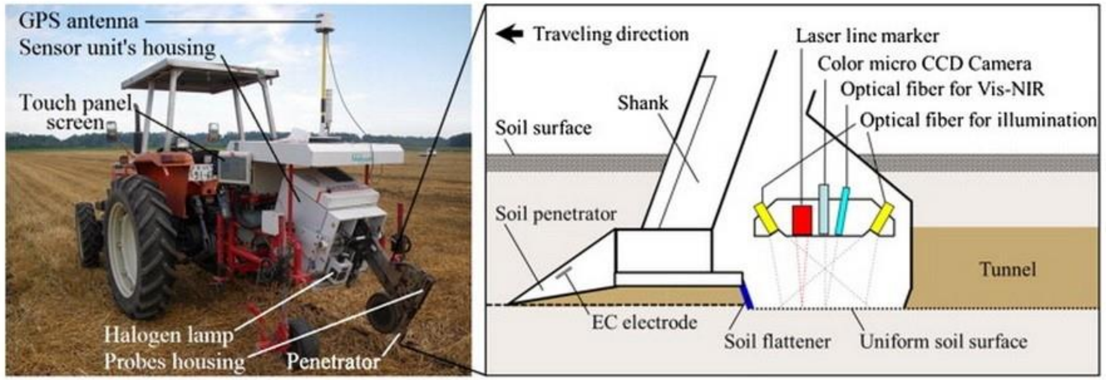
Research focus includes:

- Soil engineering (impedance and optical analysis for properties prediction)
- Image and signal processing
- Large dataset statistical analysis
- 3D thermal modeling (Ansys)

Motivation

- Low-cost sensor design for soil measurement
- Real-time measurements (i.e. on-the-going tractor)
- Accurate soil properties prediction



M Kodaira, S Shibusawa, Using a mobile real-time soil visible-near infrared sensor for high resolution soil property mapping, Geoderma, 2012

Dataset for laboratory analysis

- Data collecting

  Dataset A (fertilized field soil)

  Dataset B (fertilized field soil)

- Soil samples preparation in laboratory (drying, sieving, fertilization, etc.)
- Chemical soil characterization at certified Laboratory at Agriculture Institute of Slovenia

TABLE II. CHEMICAL CHARACTERIZATION OF THE SOIL SAMPLES FROM DATASET A.

Soil ID	Added fertiliser	P, mg/100g	K, mg/100g	M, mg/100g	Code
1	none	3.9	6.4	23	002
2	0.05% F1	14	6.4	24	102
3	0.05%P+0.05% F2	16	15	25	112
4	0.1%K	4.2	44	23	042
5	0.1% F1+0.1% F2	39	47	23	342
6	0.05% F3	7.8	14	22	012
7	0.1% F3	12	17	22	112

F1: Triple super phosphate (P2O5 -46%); F2: potassium sulphate (K2O - 50%); F3: Potassium phosphate (14% P2O5, 28%K2O, 2%MgO).

TABLE III. CHEMICAL CHARACTERIZATION OF THE SOIL SAMPLES FROM DATASET B.

Soil ID	Added fertiliser	P, mg/100g	K, mg/100g	M, mg/100g	Code
1	0.05%F1	18	13	25	112
2	0.05%F2	10	20	25	012
3	0.05%F3	11	15	29	112
4	0.05%(F1+F2+F3+F4)	23	23	30	222
5	0.1%F1	23	16	25	212
6	0.1%F3	11	16	34	113
7	0.1%F5	11	14	24	113
8	none	10	17	23	012

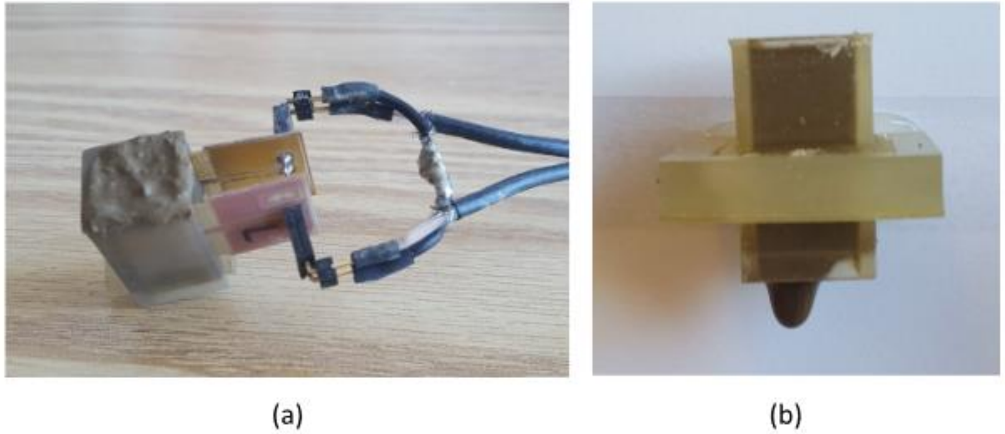
F1: calcium phosphate (P2O5 -26%, CaO - 40%); F2: potassium sulphate (K2O - 50%); F3: magnesium sulphate (MgO - 25%, SO3 - 50%); F4: potassium sulphate (K2O - 60%); F5: organic mass minimum 70%.

Agricultural Institute of Slovenia https://arhiv.kis.si/

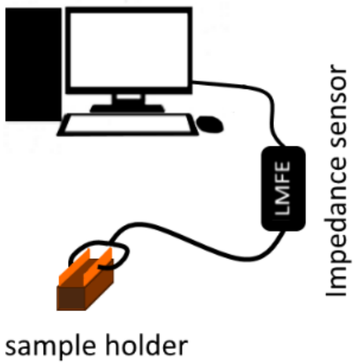
Impedance measurements

- Bulk measurement
- Impedance sensor designed in LMFE laboratory
- Matlab software for data collecting and processing

Photography of the soil bulk used for impedance measurement (a) 3D printed soil holder with a soil sample, (b) holder for soil viscosity presentation



Set-up workspace for soil impedance measurement



Impedance measurements

- Bulk measurement
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- Matlab software for data collecting and processing

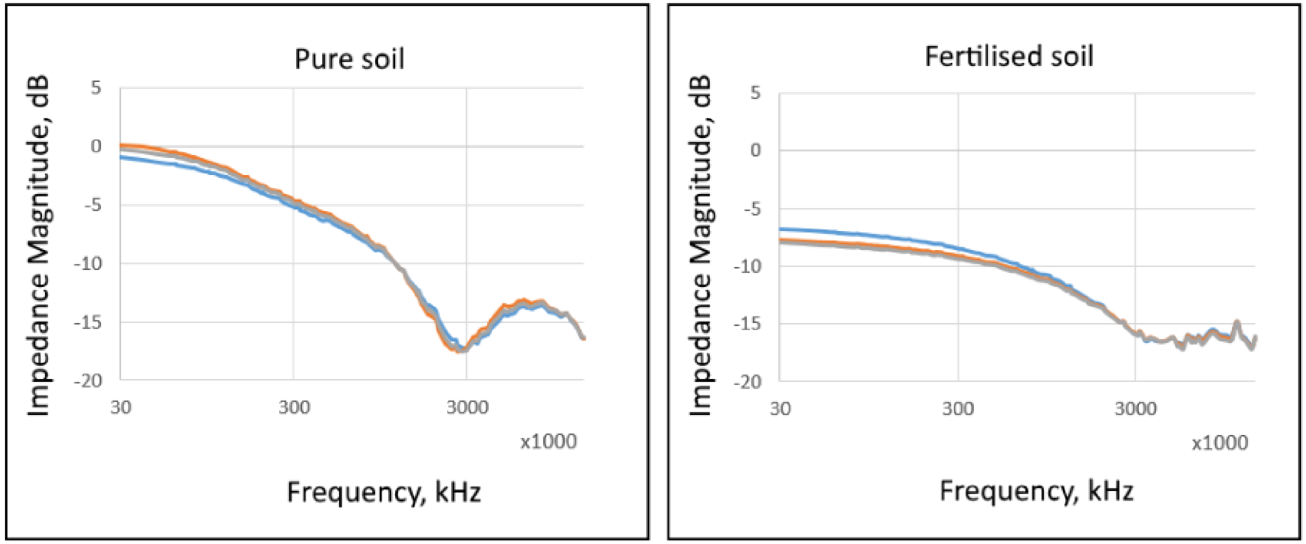


Figure 2. Impedance magnitudes of three pure soil sub-samples and three fertilized soil sub-samples respectively.

- The 122 frequencies selected between 30 kHz and 14 MHz enable a good fit of the whole frequency domain's impedance signal.
- The lower magnitudes corresponds higher fertilisation level
- Good repetitiveness of the measurements corresponding the same soil

UV-VIS-NIR spectra measurements

- Dry soil sample measurement
- Avantes VIS and NIR spectrometers
- Deuterium-halogen light box
- Matlab software for data collecting and processing

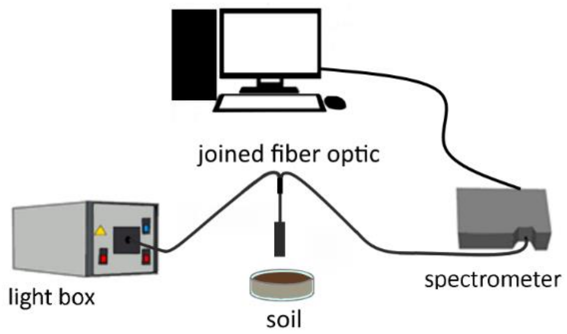


Figure 3. The experimental set-up for optical measurement

Soil sample used for measurements:

- air-dried sample
- 2-mm sieved
- 5 g placed in 3-mm glass petri dishes

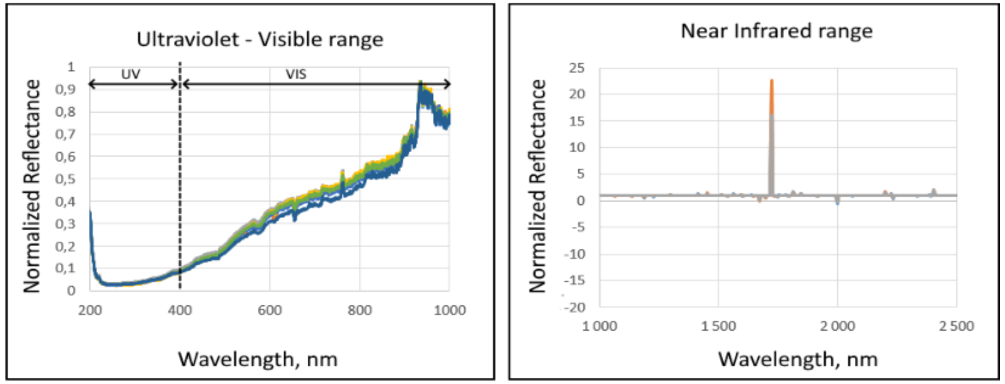


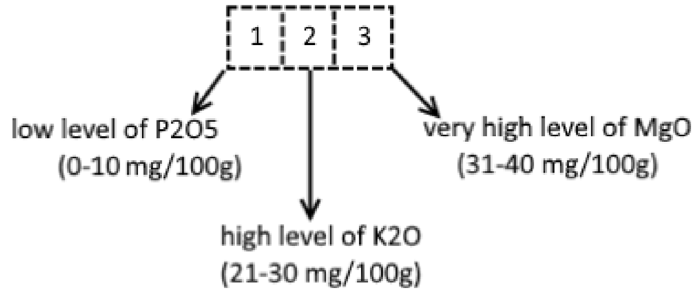
Figure 4. Normalized spectra plots obtained for pure soil in the UV-VIS range and NIR range.

Classification

- **Dataset soil class labeling**
- Feature selection (**principle component analysis**, mean value, moment invariants, etc.)
- Machine learning using training set (**decision tree**, SVM, ANN, Naïve Bayes, CNN, etc.)
- Test soil properties prediction

Soil class label formation

	Phosphorus mg/100g	Potassium mg/100g	Magnezium mg/100g
0	0-10	0-10	0-10
1	11-20	11-20	11-20
2	21-30	21-30	21-30
3	3-40	30-40	30-40
4	>40	>40	>40



Example (see table III)

Soil ID	Added fertiliser	P, mg/100g	K, mg/100g	M, mg/100g	Code
1	0.05%F1	18	13	25	112
2	0.05%F2	10	20	25	012

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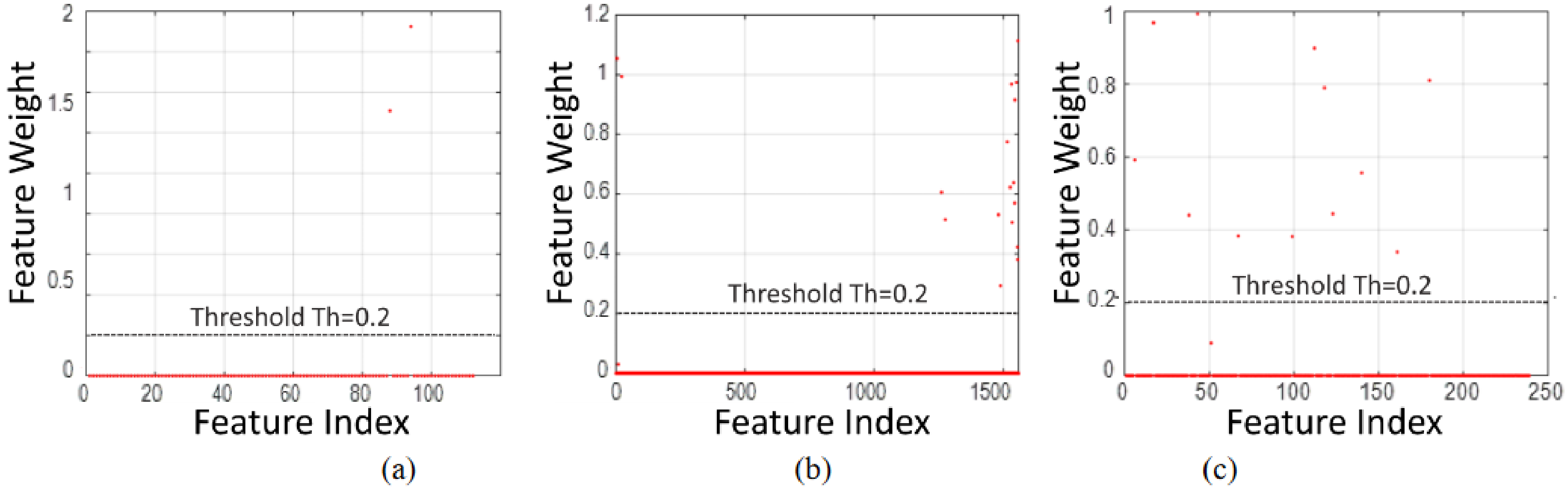
Feature weights corresponding (a) frequency domain, (b) UV-VIS range, and (c) NIR range



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- Dataset soil class labeling
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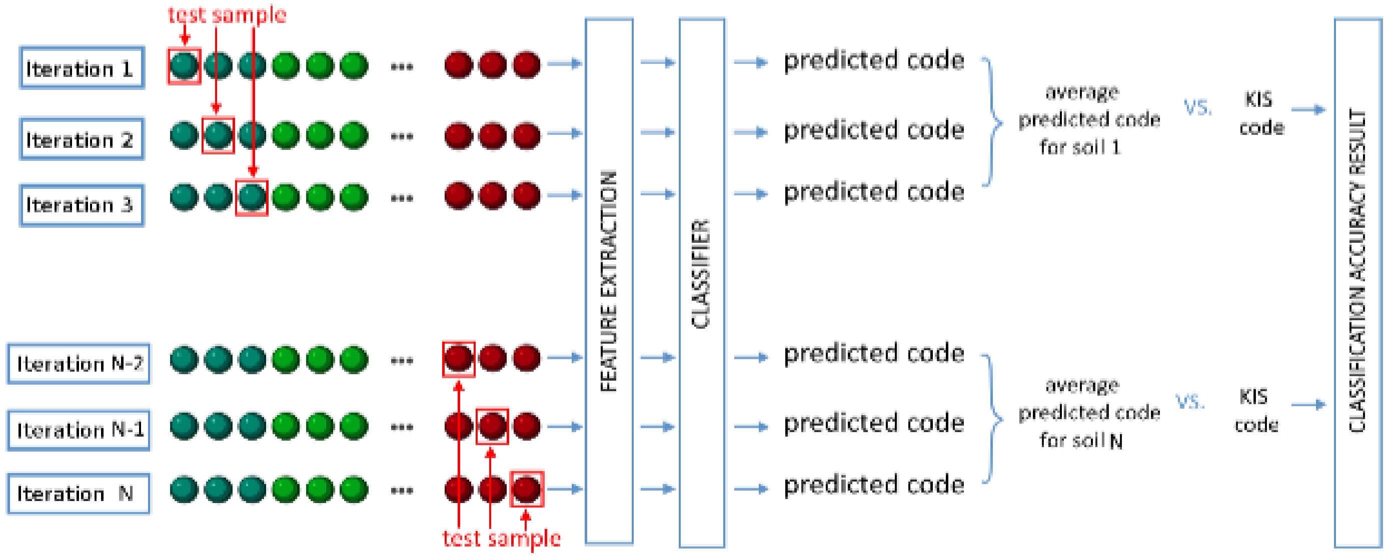
Procedure of the leave-one-out classification validation



Results comparison

TABLE IV. CLASSIFICATION RESULTS FOR DATASET A.

method of data capturing	P, mg/100g	K, mg/100g	M, mg/100g
El. impedance measurements	77%	71%	100%
UV-VIS range measurements	90%	84%	100%
NIR range measurements	90%	81%	100%

TABLE V. CLASSIFICATION RESULTS FOR DATASET B.

method of data capturing	P, mg/100g	K, mg/100g	M, mg/100g	
El. impedance measurements		75%	96%	100%
UV-VIS range measurements		80%	91%	93%
NIR range measurements		75%	92%	88%

- Both, Impedance and optic methods are effective for soil properties prediction
- UV-VIS range is more affective for analysis than NIR range
- Impedance method showed better performance for potassium prediction for dataset B
- Prediction for different fields is different

  - texture variation

  - fertility variation

  - etc.

Conclusion and further work

- Optimal procedure for impedance and optical spectra analysis is described (data preparation and classification algorithm)
- Comparative analysis indicates that the impedance method VIS range are suitable for analysis
- Both methods are good for local field fertility characterization. Nevertheless, the accuracy will deponed also on other factors such as texture that need to be investigated in future work.
- Small volume of the soil is required for analysis
- Fast measurement is possible using impedance and optic methods (less then 30 seconds)
- Dataset creating (large dataset is required)
- Multi-sensor system (combination of more then three sensors for different but compliment characteristics)

Thank you for attention