KRIGING WITH MACHINE LEARNING COVARIANTES IN ENVIRONMENTAL SCIENCES A HYBRID APPROACH

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Introduction

- Kriging
- Auxiliary variables
  - co-kriging,
  - kriging with external drift
- Machine learning methods (Artificial neural networks)
- Combining geostatistical and machine learning methods
Process overview

- Measurements

Preparation for kriging converting WGS84 => UTM

Creating projection grid fitted into flight trajectory

Variography

Kriging with external drift

Preparing training set

Training neural networks

Calculating values at nodes of the grid (machine learning)

Hybrid model estimates
Process overview

Measurements

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Equipment for measurements

Alpha Jet, based at NASA Ames Research Center

Picarro 2301-m cavity ring-down instrument for CO₂, CH₄ and H₂O

GPS that provide information about position (latitude, longitude, altitude)
Location of measurements - San Ardo

Natural gas field near San Ardo
(35°57'N - 120°52'W)
Location of measurements - San Ardo

Natural gas field near San Ardo
(35°57’N - 120°52’W)
Location of measurements - Flight path

Beginning of measurement

End of measurement

(latitude, longitude, altitude)

$\text{CO}_2$, $\text{CH}_4$ and $\text{H}_2\text{O}$

Max altitude: 1032m
Min altitude: 262m
Process overview

1. Measurements
2. Preparing data for kriging converting WGS84 => UTM
3. Creating projection grid fitted into flight trajectory
4. Variography
5. Kriging with external drift
6. Preparing training set
7. Training neural networks
8. Calculating values at nodes of the grid (machine learning)
9. Hybrid model estimates
Preparing data for kriging

Before the kriging was performed, the coordinates were converted from WGS84 coordinate system (lat/lon) into a Universal Transverse Mercator (UTM) coordinate system, to allow for computation of distances and angles using Euclidean geometry.

(latitude, longitude, altitude)
(degree, degree, meter)
(meter, meter, meter)
Process overview

- Measurements

- Preparing data for kriging converting WGS84 => UTM

- Creating projection grid fitted into flight trajectory

- Variography

- Kriging with external drift

- Preparing training set

- Training neural networks

- Calculating values at nodes of the grid (machine learning)

- Hybrid model estimates
Calculation of grid fitted into flight trajectory

- Grid contains equidistant 200 points per ellipse
- Removing points below ground level
Process overview

- Measurements
- Preparing data for kriging converting WGS84 => UTM
- Creating projection grid fitted into flight trajectory
- Variography
- Kriging with external drift
- Preparing training set
- Training neural networks
- Calculating values at nodes of the grid (machine learning)
- Hybrid model estimates
Neural networks – preparing training set

- File with the measurement data contains 2749 measured points
- Every 25\textsuperscript{th} point from that file is used as referent point
- in this way is obtained 110 referent points
- Calculating relations between referent points and other measured points is created training set of 290290 pairs
Neural networks - configuration

Inputs of neural network:

- Input1 = CurrentPoint[X].Latitude
- Input2 = CurrentPoint[X].Longitude
- Input3 = CurrentPoint[X].Altitude
- Input4 = RefPoint[Y].CO2mixingRatio
- Input5 = Distance(RefPoint[Y], CurrentPoint[X])
- Input6 = (RefPoint[Y].Latitude - CurrentPoint[X].Latitude)
- Input7 = (RefPoint[Y].Longitude - CurrentPoint[X].Longitude)
- Input8 = (RefPoint[Y].Altitude - CurrentPoint[X].Altitude)

Output of neural network:

- Output1 = estimated CO$_2$ mixing-ratio
Neural networks – Training neural networks

- Neural networks are trained using ANN training software
- Ensemble of 25 ANNS was used in interpolations
Neural networks – Training neural networks

- Ensemble of 25 ANNS was used in interpolations
- Every point from grid is calculated related to all referent points

Referent points

Projection grid

Estimation CO$_2$ concentration at one of points from grid
Process overview

1. Measurements

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4. Variography

5. Kriging with external drift

6. Preparing training set

7. Training neural networks

8. Calculating values at nodes of the grid (machine learning)

9. Hybrid model estimates
Projection grid fitted into flight trajectory

- (a) Universal kriging,
- (b) Neural networks, and
- (c) Kriging with external drift using neural network outputs as covariates
Conclusion

- neural networks cannot compete with geostatistical tools specifically developed for geospatial analysis,
- incorporation of neural networks outputs as covariates in kriging schemes, can improve the overall accuracy despite the poorer separate neural network results

Future work

- Replacing backpropagation neural networks with deep learning networks
- Replacing measurement with Alphajet with smaller UAVs?
Thank you for attention!

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