Modeling Vegetation Dynamics using Neural Networks

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T-61.6060 Data Analysis and Environmental Informatics

Outline

- Motivation
- Vegetation Measurements
- Linear Regression
- Multilayer Perceptron
- Supervised Learning and Bootstrap
- Inputs and Results
- Improvements and Stability
- Discussion

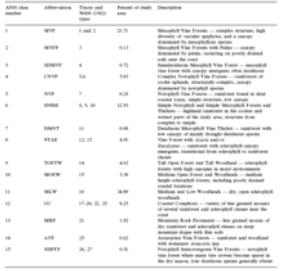
Motivation

- Water and Energy Exchange Process
- Part of Terrestrial Ecosystem
- Explain the Past
- Predict the Future
- Environmental Changes
- Agriculture and Conservation

Vegetation Measurements 1/2

- Multispectral Remote Sensing
- Past Climate Data
  - Recorded History
  - Carbon Dating and Core Samples
- Soil Samples
- Flora and Fauna Frequencies
- Classification Features

Vegetation Measurements 2/2



Linear Regression

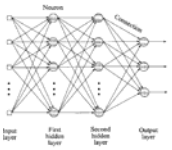
- Simplest Linear Network (Pattern Associator)
- Iterative Version of Regression

$$y(t) = \sum_{j=1}^{p} w_j(t) x_j(t)$$

$$w_j(t+1) = w_j(t) + \eta e_j(t) x_j(t)$$

Multilayer Perceptron

- Layered Feedforward Network
- Nonlinear Neuron Outputs
- Error Back-Propagation Algorithm



$$y_j^l(t) = f\left(u_j^l(t)\right)$$

$$u_j^l(t) = \sum_{i=0}^{p} w_{ji}^l(t)\, y_i^{l-1}(t)$$

$$w_{ji}^l(t+1) = w_{ji}^l(t) + \alpha\left[w_{ji}^l(t) - w_{ji}^l(t-1)\right] + \eta e_j^l(t) y_i^{l-1}(t)$$

Supervised Learning and Bootstrap

- Data Divided into
  - Training Set
  - Testing Set
- Iterate Over Multiple Epochs
  - Adaptive Learning and Momentum Rates
- Possible Bootstrapping at Each Epoch
  - Resampling of Training Set

Inputs and Results 1/3

- Landsat TM (30x30m)
  - Band 3 (Red)
  - Band 4 (NIR)
  - Band 5 (MIR)
- Standard Statistics
  - Vegetation Index (VI)
  - Normalized Difference Vegetation Index (NDVI)
- Field Surveyed Attributes
  - Loblolly Pine Age

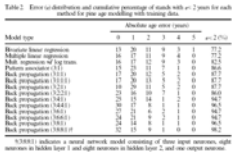


Table 2. Error (a) distribution and cumulative percentage of stands with $e \leq 2$ years for each method for pine age modelling with training data.

Model type	Absolute age error (years)						$e \leq 2$ (%)
	0	1	2	3	4	5	
Bivariate linear regression	13	20	11	9	5	1	77.2
Multiple linear regression	16	17	11	9	4	0	77.2
Mult. regression w/ log trans.	16	17	11	9	3	0	82.5
Pulsetts associator (-3:1)	15	23	11	9	1	0	86.6
Back propagation (-3:1:1)	17	20	13	9	1	0	87.7
Back propagation (-3:2:1)	17	20	13	9	2	0	87.7
Back propagation (-3:3:1)	17	20	13	9	2	0	87.7
Back propagation (-3:2:1)	23	16	10	7	1	0	86.0
Back propagation (-3:4:1)	29	15	14	1	2	0	94.5
Back propagation (-3:4:1)	30	17	6	1	1	0	96.5
Back propagation (-3:6:1)	27	21	6	1	1	0	94.5
Back propagation (-3:6:1)	24	15	9	1	1	0	94.5
Back propagation (-3:8:1)	24	14	9	1	1	0	94.5
Back propagation (-3:8:1) #	32	13	9	0	0	0	96.2

5:3:8:1: indicates a neural network model consisting of three input neurones, eight neurones in hidden layer 1 and eight neurones in hidden layer 2, and one output neurone.

$$age = 58.74 - 1.023B_4$$

Inputs and Results 2/3

- Sampled at 1 Hectare
- Vegetation Classes
- Climate Variables
- Digital Elevation Model

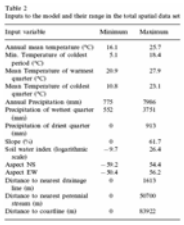
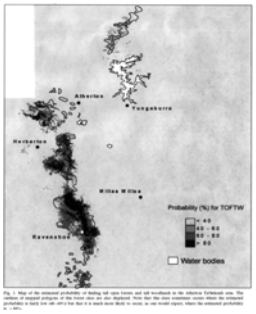
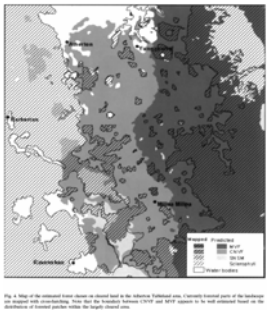


Table 2
Inputs to the model and their range in the total spatial data set

Input variable	Minimum	Maximum
Annual mean temperature (°C)	16.1	25.7
Min. Temperature of coldest period (°C)	5.1	18.4
Mean Temperature of warmest quarter (°C)	20.9	27.9
Mean Temperature of coldest quarter (°C)	10.8	23.1
Annual Precipitation (mm)	775	7066
Precipitation of wettest quarter (mm)	532	3751
Precipitation of driest quarter (mm)	0	913
Slope (°)	0	61.7
Soil water index (logarithmic scale)	−9.7	26.4
Aspect NS	−39.2	54.4
Aspect EW	−50.4	50.2
Distance to nearest drainage line (m)	0	1613
Distance to nearest perennial stream (m)	0	50700
Distance to coastline (m)	0	83922

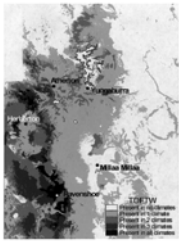
Inputs and Results 3/3





Improvements and Stability

- Exclude Distance to Coastline
- Input Climate Data for
  - 16000 BC
  - 7000 BC
  - 5000 BC
  - Present
- Analyze Stability
- Use Neighborhoods



Discussion

- Different Scales of
  - Spatial Resolution
  - Temporal Resolution
  - Continuity of Values
- Validity of Ground Truth
  - Accuracy of Field Surveys
- Explaining MLP-model