Recurrent neural networks for moisture content prediction in seed corn dryer buildings

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Introduction
- The seed is conditioned after harvest and prior to removal from the cob to prevent kernel damage and force the germ into a dormant state.
- Seed corn conditioning has not advanced significantly from the 1940’s or earlier.
- Seed corn conditioning is a relatively short part of the seed production process, yet it is crucial.
  - The conditioning step can have dramatic influence on seed quality.
  - Expensive in terms of labor, supplies, and infrastructure.
  - It is a bottleneck in the production process.
- It is time that it catch up with other aspects of corn production.
- Better MC prediction will lead to lower production costs.

Dryer building (top and bottom levels respectively)

Seed conditioning
- Heated air enters the building through the second level.
- Traditionally, air is forced upward through bin then “rolled” so that air is forced downward.
- Costs:
  - Fuel for burners.
  - Electricity to operate fans.
  - Labor:
    - Checking MC is time consuming, miserable, and slightly dangerous.
    - Farm personnel have other functions to perform.

Method
- Experimented with ESN and Elman nets.
- Training:
  - ESN: least squares fit.
  - Elman: scaled conjugate gradient descent.
  - 100 time step transient phases.
- Data:
  - Sensors placed at top and bottom of each bin.
  - Data collected from bin 1 only during 2010 harvest.
  - 26 target MC values collected by hand.
  - Total of 12 sequences:
    - 6 bin fills
    - Each fill split into up air and down air sequences.
  - 4096 sensor readings.

- Experimental parameters:
  - $N_{ov} \in \{50, 100, 150, 200\}$
  - $C \in \{0.05, 0.15, 0.25, 0.35, 0.45, 0.55\}$
  - $\alpha \in \{0.05, 0.2, 0.35, 0.50, 0.65, 0.80, 0.95\}$
  - $\beta \in \{0.05, 0.2, 0.4, 0.6, 0.8, 1.0\}$
  - $N_{h} \in \{2, 5, 8, 11, 14, 17, 20\}$
  - $M \in \{1, 6, 11, 16\}$
  - Each parameter combination run 30 times (5 times when holding each of the fills out as testing data).
  - Evaluated using NMSE on test sequences.

Results

ESN results:
<table>
<thead>
<tr>
<th>$N_{ov}$</th>
<th>$C$</th>
<th>$\alpha$</th>
<th>NMSE</th>
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</thead>
<tbody>
<tr>
<td>50</td>
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<td>0.578913</td>
<td></td>
</tr>
<tr>
<td>50</td>
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</tr>
<tr>
<td>50</td>
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<td></td>
</tr>
<tr>
<td>50</td>
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<td>0.6468151</td>
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</tr>
<tr>
<td>50</td>
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<td>0.653451</td>
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</tr>
<tr>
<td>50</td>
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<tr>
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<td>0.7399295</td>
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Elman net results:
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<th>$C$</th>
<th>$\alpha$</th>
<th>NMSE</th>
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</table>

- ESN with $\alpha = 0.05$ performed best.
  - Small spectral radius implies linear dynamics drove prediction.
  - Smaller $N_{ov}$ clearly preferred.
  - Implies only a small window historical information is used in the MC predictions.
  - Elman nets also suffered with growing net size

Conclusions and future work
- Full power of ESN may not have been necessary for this simplified model.
  - Probably necessary as model is expanded to take more variables into account.
  - Should be compared against ANN with time delay inputs.
  - Expand model to take more parameters into account.
  - Wind speed.
  - Ambient conditions.
  - Estimated moisture content of seed in all bins.
  - Run model in closed-loop mode.
  - Learn to associate data with quality metrics?
  - Learn control policy for burners and fans.
  - Optimize for cost reduction.
  - Allow user to meet variable target drying rates.
  - Expand control policy to include bypass and bin door positions.
  - Optimization of other seed plant processes.

Acknowledgments
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