Detecting Linguistic Characteristics of Alzheimer's Dementia by Interpreting Neural Models

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Alzheimer’s Disease (AD)

• Most common form of Dementia

• Caused by cortical degeneration

• Decline in language comprehension and ability

• Medication can slow or halt progression
Evaluation Techniques

- Mental Status and Mood Testing
- Physical and Neurological Exams
- Extensive Medical History
- Brain Imaging
The Task

Transcripts of Spoken Languages samples ➔ Binary Classification of AD+ or AD-
But first, let’s look at the methodology.
ML vs. DL

Image from: https://codeutsava.in/blog/40
GOAL: Have computers understand natural language to perform useful tasks.
NLP + Deep Learning

Classical NLP

Deep Learning

Back to the task...
Dataset

- Dementia Bank dataset
- Transcripts and speech samples
- Non-AD + AD Patients
- Includes POS tags
  - Noun, verb, adjective, adverb, present participle, determiner, etc.

Image from: https://www.researchgate.net/figure/The-Cookie-theft-picture_fig1_317095410
## Previous Works

<table>
<thead>
<tr>
<th>Author</th>
<th>ML vs. DL</th>
<th>Description</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rudzicz et al.</td>
<td>Machine Learning</td>
<td>Extracted over 200+ lexical features</td>
<td>67.0%</td>
</tr>
<tr>
<td>Orimaye et al.</td>
<td>Machine Learning</td>
<td>Used syntactic, lexical, and n-gram features</td>
<td>86.1%</td>
</tr>
<tr>
<td>Konig et al.</td>
<td>Machine Learning</td>
<td>Analyzed speech audio</td>
<td>87.0%</td>
</tr>
<tr>
<td>Orimaye et al.</td>
<td>Deep Learning</td>
<td>Deep Neural + Language Model</td>
<td>87.5%</td>
</tr>
</tbody>
</table>
Neural Models

Recurrent Neural Network (RNN)

Convolutional Neural Network (CNN)

Convolutional/Recurrent Neural Network (CNN-RNN)

Images from: http://colah.github.io
# Results

<table>
<thead>
<tr>
<th>Author</th>
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</tr>
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<td>Machine Learning</td>
<td>Speech audio</td>
<td>87.0%</td>
</tr>
<tr>
<td>Orimaye et al.</td>
<td>Deep Language Model</td>
<td>Transcripts</td>
<td>87.5%</td>
</tr>
<tr>
<td>-</td>
<td>CNN</td>
<td>Transcripts</td>
<td>82.8%</td>
</tr>
<tr>
<td>-</td>
<td>RNN</td>
<td>Transcripts</td>
<td>83.7%</td>
</tr>
<tr>
<td>-</td>
<td>CNN-RNN</td>
<td>Transcripts</td>
<td>84.9%</td>
</tr>
<tr>
<td>-</td>
<td>CNN-RNN</td>
<td>Transcripts + POS</td>
<td>91.1%</td>
</tr>
</tbody>
</table>
But what did the neural model look at?
Saliency Heat Maps

True label: Alzheimer's, Predicted: Alzheimer's
Saliency Heat Maps

True label: Control, Predicted: Control

Input Text

stool
um
that
off
falling
is
boy
the
uh
Saliency Heat Maps

True label: Alzheimer's, Predicted: Control
Activation Clustering

Activation Clustering

• Short answers and bursts of speech
  • “Okay”, “yes”, “oh!”, “yes”, “fine”

• Repeated requests for clarification
  • “Did I say facts?”, “Did I get any?”, “Did I say elephant?”

• Starting with interjections
  • “Well I gotta see it”, “Oh I just a lot of uh…”, “So all the words that you can”
# Activation Clustering

<table>
<thead>
<tr>
<th>POS</th>
<th>AD Frequency</th>
<th>Non-AD Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>0.20</td>
<td>$n$ 0.15</td>
</tr>
<tr>
<td>$det$</td>
<td>0.14</td>
<td>$det$ 0.13</td>
</tr>
<tr>
<td>$adj$</td>
<td>0.05</td>
<td>$presp$ 0.07</td>
</tr>
<tr>
<td>$adv$</td>
<td>0.04</td>
<td>$part$ 0.05</td>
</tr>
</tbody>
</table>
Conclusion

• Applied 3 different neural models to AD classification
• Achieved a new benchmark accuracy
• Utilized two visualization techniques
Future Work

- Multi-class classification to differentiate among stages

- Apply to other neurological diseases:
  - Huntington’s
  - Diffuse Lewy Body

- How early can we catch AD in language?
  - Agatha Christie and Iris Murdoch novels
Questions?