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

Sweta Karlekar
Computer Science, UNC Chapel Hill
Graduate Student: Tong Niu
Research Mentor: Dr. Mohit Bansal
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

Machine Learning

- Input
- Feature extraction
- Classification
- Output

Deep Learning

- Input
- Feature extraction + Classification
- Output

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

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

Recurrent Neural Network (RNN)

Convolutional Neural Network (CNN)

Convolutional/Recurrent Neural Network (CNN-RNN)

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

| Author       | Model              | Description                  | Accuracy |
|--------------|--------------------|------------------------------|----------|
| Rudzicz et al. | Machine Learning   | 200+ lexical features        | 67.0%    |
| Orimaye et al. | Machine Learning   | Syntactic, lexical, and n-gram features | 86.1% |
| Konig et al. | Machine Learning   | Speech audio                 | 87.0%    |
| Orimaye et al. | Deep Language Model | Transcripts                  | 87.5%    |
|              | CNN                | Transcripts                  | 82.8%    |
|              | RNN                | Transcripts                  | 83.7%    |
|              | CNN-RNN            | Transcripts                  | 84.9%    |
|              | CNN-RNN            | Transcripts + POS            | 91.1%    |
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

stool
um
that
off
falling
is
boy
the
uh

Input Text
Saliency Heat Maps

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

Image from: https://towardsdatascience.com/applied-deep-learning-part-1-artificial-neural-networks-d7834f67a4f6
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

|      | AD         |          | Non-AD        |          |
|------|------------|----------|--------------|----------|
| POS  | Frequency  | POS      | Frequency    |          |
| `n`  | 0.20       | `n`      | 0.15         |          |
| `det`| 0.14       | `det`    | 0.13         |          |
| `adj`| 0.05       | `presp`  | 0.07         |          |
| `adv`| 0.04       | `part`   | 0.05         |          |
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?