“Do I Hear 3NT?”: Learning a Bridge Bidder
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**Predicting**
- This project attempts to learn the optimal classification for two important sub-problems of Bridge’s bidding phase
  - Given a 13-card hand, which of 36 possible opening bids should the player use?
  - Given two 13-card hands, in which of 36 possible final contracts should the team end?
- An opening bid and a final contract can each be one of Pass or [1-7][NT|S|H|D|C]
- Bidding in Bridge is a nuanced problem that takes human players a long time to learn; possibly extensible to state-based or logic-based AI with learning underpinning

**Data**
- Data is from tournament hands played by human experts and other computer agents available from a variety of sources that publish results of their tournaments
  - Opening bid data starts with 13 card hands for each of 4 players and sequence of bids
  - Translate to hand-bid labeled data for each player up to and including first non-Pass bid
  - Possible multiple labels: only training and testing if no disagreement, reporting two error figures
  - Final contract data requires processing to label ground truth (solving full-information game tree problem, uses 3rd party library)

**Models and Features**
- Softmax regression using two types of features. Maximize log-likelihood:
  \[
  l(\theta) = \sum_{i=1}^{m} \log \prod_{j=1}^{36} \left( \frac{e^{\theta_j^T x(i)}}{\sum_{j=1}^{36} e^{\theta_j^T x(i)}} \right)^{1(y^{(i)} = j)}
  \]
  using stochastic gradient ascent:
  \[
  \theta = \theta + \alpha \left( \frac{1}{1+\sum_{j=1}^{36} e^{\theta_j^T x(i)}} \right) (y^{(i)} - \hat{y}(\theta, x(i))) x(i)
  \]
- Two feature extractors:
  - Raw card indicators: for all 52 cards
  - Limited domain knowledge indicators: # cards per suit, number of high card points per suit and total

**Results**
- *Opening bid problem*: low error, model generalizes well, and misclassifications are on borderline decisions for human players (and many of those classify correctly)
  - Train Error
    - Agreed
    - All
    - Labels
    - 16.6K
    - 9.6K
    - 4.7K
    - 2.7K
  - Dev Error
    - Agreed
    - All
    - Labels
    - 16.0%
    - 10.4%
    - 16.9%
    - 11.1%
  - Raw feat.
    - 16.0%
    - 10.4%
    - 16.9%
    - 11.1%
  - Domain feat.
    - 10.3%
    - 5.3%
    - 12.5%
    - 6.6%
- *Final contract problem* has not had positive results yet (see discussion and future work)

**Discussion**
- Opening bid results with simple domain features are better than expected
  - Raw card features generalize better than expected
  - Problem may be simpler than seems
    - Fewer than 36 classes with large probabilities
    - Relatively rote decision for human players, more nuance introduced with sequential bids
  - Final contract model oversimplifies and predicts few classes, with additional time refining would be a key next step

**Future Work**
- Final contract problem: additional features, debugging model/algorithm
- Sequential bidding agent: incorporate state- and/or logic-based model
- Learning vs. programming: in competition, must follow explainable conventions

**References**
- Mernagh, Michael, “Learning a Double Dummy Bridge Solver”, 2016 CS229 Final Project