LEARNING FROM DIFFERENT PERSPECTIVES: ROBUST CARDIAC ARREST PREDICTION VIA TEMPORAL TRANSFER LEARNING

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CARDIAC ARREST PREDICTION & PREVENTION

- Greatest challenges of contemporary cardiology
  - ~80% in-hospital mortality rate
  - 300,000 deaths in the US annually
- Early warning / risk stratification only look at summary statistics of vital signs
  - Ignore temporal patterns
  - Unable to identify high-risk patients with sufficient intervention time
CARDIAC ARREST PREDICTION: SETUP

Event Time

$X_1$  $t = 1$

$X_2$  $t = 2$

$X_3$  $t = 3$

$X_4$  $t = 4$
CARDIAC ARREST PREDICTION: SETUP

Event Time:

- $t = 1$ for $X_1$
- $t = 2$ for $X_2$
- $t = 3$ for $X_3$
- $t = 4$ for $X_4$

Time point of interest
CARDBIAI ARREST PREDICTION: SETUP

Observation window
or training data

Time point of interest
CAPTURING TEMPORAL TRENDS IN MACHINE LEARNING MODELS

- Standard “static” models: logistic regression, support vector machines, decision trees
  - Temporal trends need to be encoded as features
  - Insufficient data to fit time point of interest models
- “Dynamic” models: state-space models, multivariate matrix normals, Gaussian processes, etc.
  - Less interpretable compared to risk-stratification systems due to “black”-box nature
TTL-REG: TEMPORAL TRANSFER LEARNING BASED MODEL

- Pose estimation of coefficients at different time points as related tasks
- Borrow information from adjacent time points by smoothing estimated coefficients between time point before $(z - 1)$ and time point after $(z + 1)$

$$f(\beta) = \sum_{k=1}^{T} \ell(y_k, X_k \beta_k) - \sum_{k=1}^{T-1} \frac{\lambda}{2} ||\beta_t - \beta_{t+1}||_2^2 - \sum_{k=2}^{T} \frac{\lambda}{2} ||\beta_t - \beta_{t-1}||_2^2$$
TTL-REG: TEMPORAL TRANSFER LEARNING BASED MODEL

- Pose estimation of coefficients at different time points as related tasks
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\[
f(\beta) = \sum_{k=1}^{T} \ell(y_k, X_k \beta_k) - \sum_{k=1}^{T-1} \frac{\lambda}{2} \| \beta_t - \beta_{t+1} \|^2_2 - \sum_{k=2}^{T} \frac{\lambda}{2} \| \beta_t - \beta_{t-1} \|^2_2
\]

Regularization parameter controls amount of information shared between adjacent points
DATA: MIMIC-II

- Publicly available intensive care unit (ICU) database
  https://mimic.physionet.org/

- 7 features: temperature, peripheral capillary oxygen saturation, heart rate, respiratory rate, diastolic blood pressure, systolic blood pressure, and pulse pressure

- 763 elderly (aged 50+) patients with 197 of them experiencing a cardiac arrest event (~26% prevalence)
DATA: PATIENT EXAMPLE

observation window = 12

variable
- hr
- rr
- temp
- spo2
DATA: PATIENT EXAMPLE

observation window = 12

last observed measurement + median imputation for missing data
BASELINE MODELS: AUC + ESTIMATED COEFFICIENTS

<table>
<thead>
<tr>
<th>Hour</th>
<th>Train Mean</th>
<th>Train SD</th>
<th>Test Mean</th>
<th>Test SD</th>
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<tr>
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<td>0.6588</td>
<td>0.0155</td>
<td>0.6137</td>
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<tr>
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<td>0.6220</td>
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<td>0.0125</td>
<td>0.5941</td>
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<td>0.0179</td>
<td>0.6306</td>
<td>0.0397</td>
</tr>
</tbody>
</table>

Variable: hr - ppi - rr - sBP - temp
TTL-REG MODEL: AUC + ESTIMATED COEFFICIENTS
DISCUSSION + CONCLUSION

- Temporal transfer learning by smoothing coefficients of adjacent time points
  - Yields coefficient trajectories that are easily interpreted
  - Provides improved early prediction of cardiac arrest
- Future work
  - Explore various prediction problems (readmission, etc.)
  - Explore different classification models (SVM, decision tree, etc.)
Q&A

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