Multi-Dimensional Interpretable Interaction Network (MDiiN) for Modeling Aging Health and Mortality

**Aging and Age-Related Diseases**
- A biological process during lifespan with accumulation of mutations and damages.
- The most critical risk factor associated with many diseases.
- Accounts for 2/3 of deaths worldwide.

**What We Don’t Know**
- What is the biological mechanism of aging?
- What connects aging to diseases?
- Can we better prepare our elders?

**Research Goal and Challenges**
- Use a stochastic differential equation with a neural network to model how longitudinal aging progresses over time.
- Few Research Few methodologies have been developed to model longitudinal aging process.
- Stochastic Aging is the result of a set of random changes that accumulated over time.
- High-Dimensional A high-dimensional process through various pathways in which healthy functioning can change with age.
- Stochastic Differential Equation Simulating the aging process with an SDE is an emerging area of aging research.

**MDiiN Architecture and Workflow**
- 1. Impression Encoder
- 2. Pairwise Health Matrix $N \times N$ (of health variables)
- 3. Three-Dimensional Interaction Network
- 4. Stochastic Differential Equation $dx(t) \rightarrow x(t)$
- 5. Gated Recurrent Unit

**Experiment Results**
- 1. Effectiveness of MDiiN C-index vs Age Brier Score for the Survival Score vs Death Age
- 2. RMSE Measurements
- 3. RMSE Score Relative to How Long after the Baseline the Predictions are Made
- 4. Interpretable Interaction Network
- 5. Comparison with Latent Space Models of Varying Dimension

**Application**
MDiiN can monitor people at risk for illness and mortality based on their health history. My model can identify and prevent them from a severe illness from COVID-19 and help us better respond to future threats.

MDiiN can estimate values for missing data for health records, preserving all cases and eliminating data bias.

**English Longitudinal Study of Aging (ELSA)**
- Baseline + 10 Waves, 22 years
- Wave 0
- Wave 1
- Wave 2
- Wave 3
- Wave 4
- Wave 5
- Wave 6
- Wave 7
- Wave 8
- Wave 9
- Wave 10

**Follow-up From Entrance Wave**
- Number of individuals with measurements
- Training and Testing Data
- Age Distribution

**Project Significance**
MDiiN is the first three-dimensional interaction network to uncover high-dimensional interactions among health variables during the aging process.

MDiiN is one of the first complete SDE models that can predict an individual’s health state and survival rate at any time.

MDiiN outperformed Elastic-Net in most metrics (C-Index = 0.9 vs 0.65 and Integrated Brier Score = 0.3 vs 0.6), and is comparable to the Elastic-Net for D-Calibration (p = 0.9 vs 1.0).

MDiiN is comparable to other high-dimensional models in prediction.

MDiiN’s interpretability is visualized through a pairwise correlation network of the various health variables.

**Future Work**
The MDiiN model can be extended to a wide range of high-dimensional health data, and ultimately improve our understanding of aging process and benefit public health.

Suppression of aging itself should delay or treat all age-related diseases, thus increasing healthy life span and maximal longevity.

Revealing the underlying causes of aging can help develop anti-aging medicine to keep us stay healthy and biologically efficient.

**Data Imputation Tool**

**Health Monitoring and Prevention Tool**

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