

Aladynoulli: A Dynamic Model for Disease Progression

Understanding Cardiovascular Risk Through Temporal Pattern Analysis

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Outline

- 1 Model Overview
- 2 Mathematical Framework
- 3 Clinical Example
- 4 Model Benefits
- 5 Future Directions

The Big Picture

Key Ideas

- Individual risk profiles evolve over time
- Diseases share underlying risk factors
- Genetic factors influence progression
- Time-varying disease relationships

Clinical Relevance

- Personalized risk trajectories
- Natural disease progression
- Multiple disease interactions
- Treatment planning implications

Individual Risk Profiles (λ)

Individual-Specific Topic Scores

For each individual i , topic k , and time t :

$$\lambda_{ik}(t) \sim \mathcal{GP}(\Gamma_k^T g_i, \Sigma_k)$$

Components:

- g_i : Genetic covariates
- Γ_k : Genetic effects
- Σ_k : Temporal covariance

Clinical Meaning:

- Personal trajectories
- Genetic influence
- Smooth evolution

Topic Proportions (θ)

From Scores to Proportions

Via softmax transformation:

$$\theta_{ik}(t) = \frac{\exp(\lambda_{ik}(t))}{\sum_{j=1}^K \exp(\lambda_{ij}(t))}$$

Properties:

- $\theta_{ik}(t) \in (0, 1)$
- $\sum_k \theta_{ik}(t) = 1$
- Smooth changes

Interpretation:

- Relative risk weights
- Competing factors
- Dynamic profiles

Disease Topic Loadings (ϕ)

Disease-Topic Relationships

For each disease d and topic k :

$$\phi_{kd}(t) \sim \mathcal{GP}(\mu_d, \Omega_k)$$

Components:

- μ_d : Base disease risk
- Ω_k : Topic covariance

Clinical Meaning:

- Topic-disease links
- Disease patterns
- Time variation

Disease Probabilities (π)

Individual Disease Risk

Probability for individual i , disease d , at time t :

$$\pi_{id}(t) = \sum_{k=1}^K \theta_{ik}(t) \cdot \text{sigmoid}(\phi_{kd}(t))$$

Components:

- Personal risk profile
- Topic contributions
- Temporal dynamics

Clinical Use:

- Risk prediction
- Trajectory planning
- Intervention timing

Cardiovascular Risk Profiles

Three Key Risk Domains

1 Metabolic Risk

- Strong diabetes link
- Gradual vascular impact

2 Vascular Risk

- Primary CAD driver
- Early HTN effects

3 Inflammatory Risk

- Accelerated progression
- Late complications

Disease Progression Patterns

Temporal Sequence

① Early Stage

- Hypertension
- Metabolic changes

② Mid Stage

- Type 2 Diabetes
- Early CAD signs

③ Late Stage

- Clinical CAD
- Heart Failure

Key Advantages

Clinical Strengths:

- Personalization
- Natural progression
- Multiple diseases
- Interpretable

Statistical Power:

- Temporal smoothing
- Uncertainty measures
- Principled inference

Practical Impact

- Better risk stratification
- Informed treatment planning
- Early intervention opportunities

Next Steps

Clinical Applications

- Risk stratification tools
- Treatment optimization
- Prevention strategies

Model Extensions

- Treatment effects
- Environmental factors
- Additional outcomes
- Real-world validation