Cause-Specific Senescence: Classifying Causes of Death According to the Rate of Aging

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IDEAS
- Background: Recent International Classification of Diseases (ICD10) contains around 12,000 causes of death (CODs).
- Reasoning: Cause-specific data contain two types of information: medical content based on the definition; intrinsic age profile.
- Research question: Are there common age-specific mortality patterns based on CODs?

DATA
- Death counts: individual-level data from Czech Republic in 1998-2011 by CODs.
- Exposures: Human Mortality Database.
- Selection: males, 1-year age group 30-100; 3-digits level of ICD10; CODs with 10+ available data-points over ages.
- Final dataset: Deaths $D = (d_i)$, Exposures $e = (e_i)$, $i = (1, \ldots, m-71)$ ages, $c = (1, \ldots, n = 531)$ CODs.

CLUSTERING
- We aim to classify all $n$ CODs by $r(s)$ reduced to a vector of $(s - 1)$ lagged-coefficients for each COD $c$:
  $$\begin{align*}
  \alpha_1, \alpha_2, \ldots, \alpha_{s-1} \\
  \end{align*}$$
- We use k-means clustering which allows to:
  1. classify cause-specific rates of aging
  2. extract distinct aging profiles (cluster centers).
- We partition $n = 531$ observations into $k$ sets $S = \{S_1, S_2, \ldots, S_k\}$:
  $$\begin{align*}
  \arg\min \sum_{i=1}^{k} \sum_{c \in S_i} (\alpha^2 - \hat{\alpha}_i)^2 \\
  \end{align*}$$

ESTIMATING RATE OF AGING
- Cause-specific rate of aging:
  $$r(x) = \frac{\mu(x)}{\mu'(x)}$$
- $\mu'(x)$: cause-specific force of mortality
- Non-parametric data model:
  $$\mu''(x) - B^2 \mu = 0$$
- $B^2$: matrix of order $1 - 17$ B-splines of degree $q$ equally spaced by a distance $h$:
  $$\hat{\beta}$$: cause-specific penalized coefficients
- Cause-specific rate of aging is both:
  1. derived by the linear combination of B-splines:
  2. obtained by difference operator on coefficients.
- $r = C \hat{\beta}^T = \hat{\beta}^T \cdot \alpha$
- $C$: matrix of first order difference of $B^T$, $\alpha$: first difference of $\hat{\beta}$

CLUSTERING
- Decreasing rate of aging
- log-linear force of mortality
- rapid increase of $\mu(x)$ at age 60 and deceleration afterward.

SUMMARY
- Using non-parametric techniques, we estimated instantaneous cause-specific rate of aging.
- We carried out a cluster analysis on cause-specific rate of aging.
- We selected the optimal number of clusters.
- We identified three distinct age patterns of human mortality:
  1. age-independent
  2. rising constantly with age
  3. decelerating mortality at older ages.
- This grouping could be used to refine mortality model and forecast analysis.

CAUSE-SPECIFIC SENESCENCE PROTOTYPES

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