Invariant density analysis of postural sway and prospective fall risk in community-dwelling elderly

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Motivation

- The goal of MOBILIZE Boston study (MBS) is to find risk factors of falls in elderly adults
- Huge amount of MBS data sets of center of pressure (COP) is ready
- We already developed a novel tool to analyze COP

We apply this tool to MBS data set and see if this tool can be used as a prediction model for fall risks

MOBILIZE Boston Study (MBS)

- A National Institute of Aging (NIA) funded program
- A prospective cohort study of a unique set of risk factors for falls in seniors in the Boston area
- 765 elderly persons aged 70 and older participated in the study as of January 2008

Mobilize Boston
Community Senior Health Study

MBS data collection

- Home interview
  - Chronic conditions, pain, falls, cognition, depression, and etc.
- First clinic visit: baseline data collection
- Second clinic visit: 18 month follow-up
- Data collected during clinic visit
  - Balance, mobility performance, muscle strength, vision, and etc.
- Monthly fall occurrence calendar

SG Leveille et al. BMC Geriatr 8:16, 2008

Invariant Density Analysis (IDA)

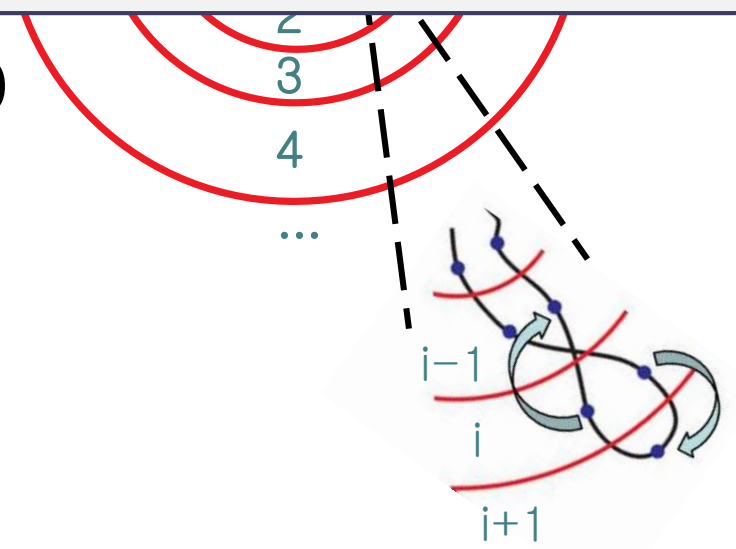
- Analyze COP dynamics using stochastic approach (Markov chains)
  - Describe COP fluctuations with probability distributions of transitioning from one state to another
  - Long term COP behavior can be captured by the **"invariant density" (π)** i.e., stationary/steady-state probability distribution

Algorithm to get in

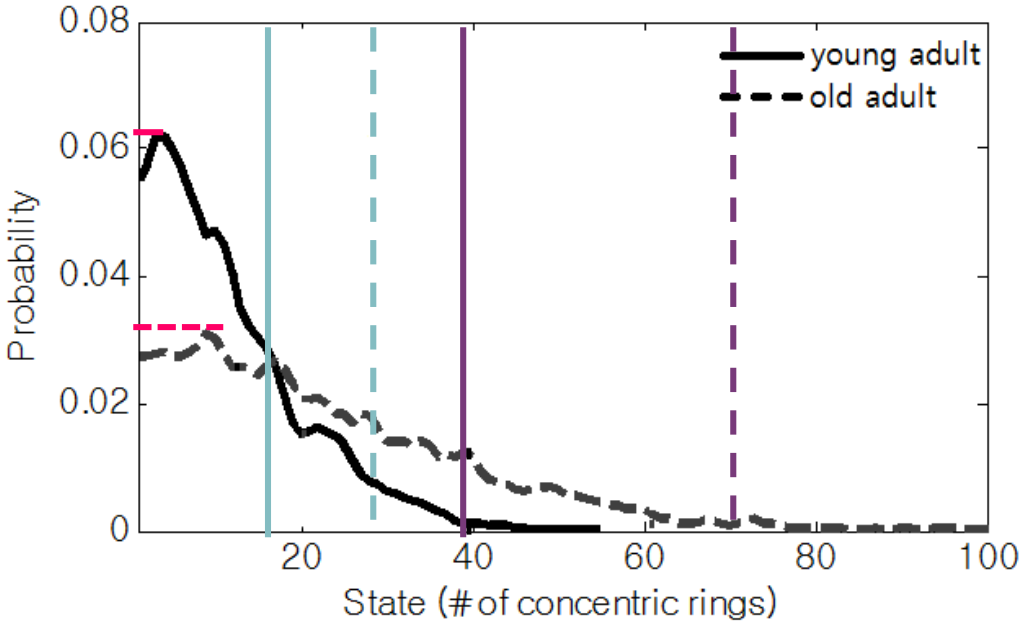
- Find centroid of COP
  - Zero mean adjustment
- Define states as concentric rin
  emanating from centroid
  (states separated by 0.2 mm)
- Construct the transition matrix (**P**)
  - **P** contains probabilities of transitioning from one state to another
- Solve for the invariant density (π)
  - $\pi = \pi P$

Next state

Current state	1	2	3	…
1	0.5	0.3	0.2	…
⋮	⋮	⋮	⋮	…



Invariant density plot



Plots of invariant density distributions (π) for young and older adults [Hur 2009]

Parameters

Ppeak – Probability of being in the state with maximum likelihood

MeanDist – average state of COP sway

D95 – state below which 95% of COP points occur

EV2 – 2nd largest eigenvalue, rate of convergence to π

Entropy – randomness of system (high → more random, $-\Sigma\pi(i)\log_2\pi(i)$)

P Hur et. al. ASME Summer Bio Conf, Lake Tahoe, CA. June, 2009

Experimental protocol

- Quiet standing (QS) on forceplate (Kistler) with sampling rate of 240 Hz
- Ten 30 sec trials with eyes open
  - Five for normal QS,
  - Five for dual cognitive task with serial subtraction by 3
- We only used normal QS data for the analysis

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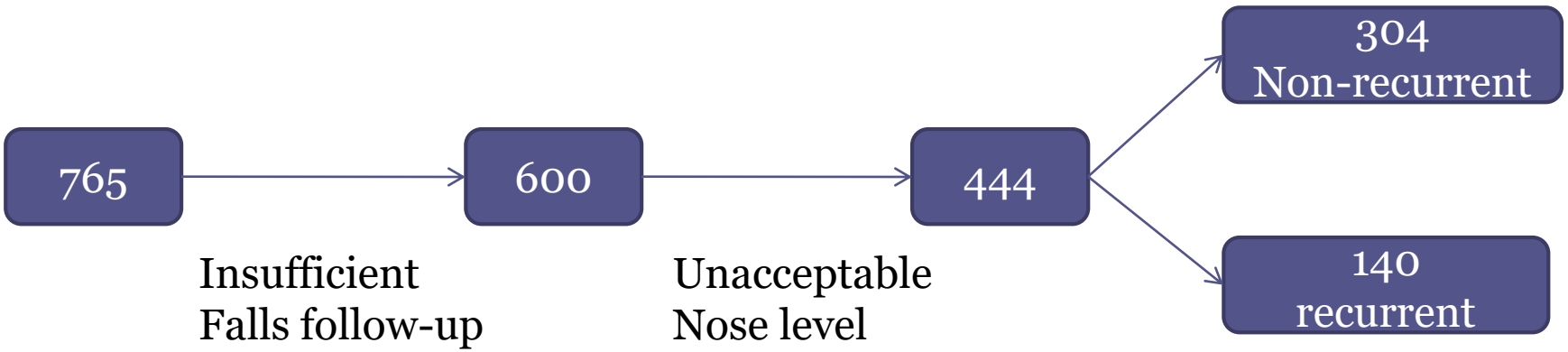
Classification of Recurrent fallers

- Recurrent fallers : subjects with more than two falls within a year of study
- Non-recurrent fallers : subjects with 0 or 1 fall



Results

- Non-recurrent fallers more tend to stay within certain state (***Ppeak***)
- Recurrent fallers are likely to sway more away from centroid (***MeanDist***)
- Recurrent fallers wander wider (***D95***)

	Non recurrent fallers	Recurrent fallers	p-value
Ppeak	0.047±0.0001	0.043±0.001	0.007
MeanDist	3.53±0.06	3.98±0.14	0.001
D95	8.43±0.15	9.56±0.33	<0.001

Results

- Recurrent fallers sway in more random manner (***Entropy***)
  → It may imply recurrent fallers have less degree of active control to keep COP close to centroid
- Even though not statistically significant, it may be suggested that COP of recurrent fallers converge more slowly to a steady-state behavior (***EV2***)

	Non recurrent fallers	Recurrent fallers	p-value
Entropy	5.33±0.025	5.47±0.038	0.001
EV2	0.9992 ± 10^{-5}	0.9993 ± 10^{-5}	0.072

Conclusion and future work

- IDA can successfully differentiate RF from NF.
- COP of RF were found to fluctuate in a more random behavior than NF.
- We will develop a fall risk estimation model using multiple linear regression model.

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Mobilize Boston
Community Senior Health Study

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Thank you

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