Population Level Behavior Analysis in Smart Environments

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Overview

Hypothesis

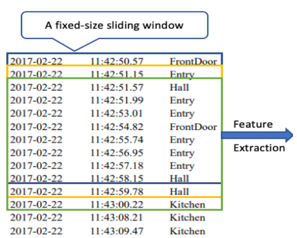
Formal modeling and analysis of human behavior can properly advance disciplines ranging from psychology to economics.

Formal Models of Human Indoor Routine Patterns

- Analyze the inter-arrival times of activities (e.g. Eat, Cook)
  ➔ Heavy tailed distributions, the Pareto distribution
- Investigate the relationship between formal models and a resident health status
  ➔ Bed to toilet transitions reflect mobility difficulties
- Predict subgroup classifications from inter-arrival times
  ➔ 81.4% prediction accuracy from Work inter-arrival times
- Investigate interdependencies of certain activities both at 99 smart homes and among subgroups
  ➔ Bivariate or multivariate Pareto distributions
- Construct Markov models for activities and locations
  ➔ Selected orders of Markov model for indoor behavior
  ➔ Different order of MC and a resident's health status
- Build up a model combine more elements (e.g. social interactions and time spent in locations) (future)

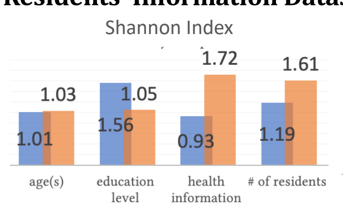
Datasets

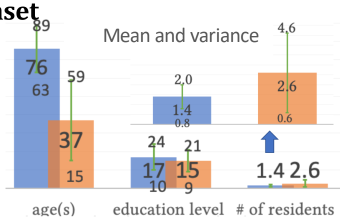
Smart Home Dataset



Description
Hour of day for current event
Seconds since the start of the day for the current event
Window duration
Seconds since previous event
Most frequent event sensor in the previous window
Most frequent event sensor in the window before that
Current event sensor
Most recent location sensor
Number of events in the window for each sensor
Time since last fired for each sensor
Maximum value of sensor
Complexity of events in window
Number of motion events in window

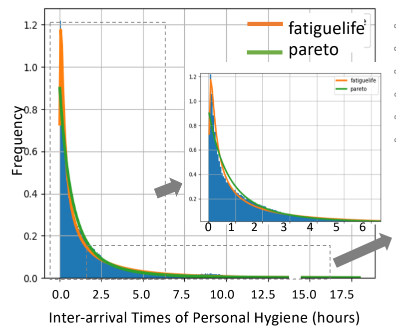
Residents' Information Dataset

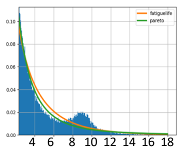


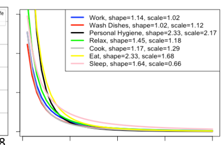


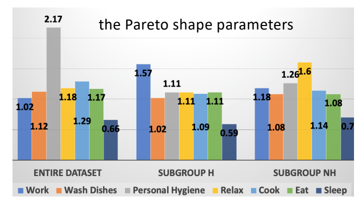
Modeling Fitting

Inter-Arrival Times of Each Activity

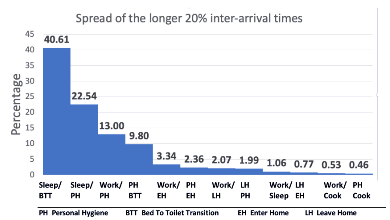


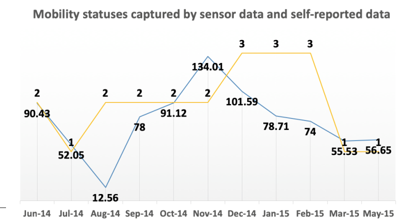






Inter-Arrival Times of Sequences of Activities





Interdependencies of certain activities

$$F_{entire}(x_{work}, x_{eat}) = \left(1 + \frac{x_{relax}+1.14}{1.14} + \frac{x_{eat}+1.61}{1.61}\right)^{-1.17}$$

$$F_{subgroupNH}(x_{washDishes}, x_{eat}) = \left(1 + \frac{x_{washDishes}+1.31}{1.32} + \frac{x_{eat}+1.17}{1.17}\right)^{-1.08}$$

$$F_{subgroupH}(x_{PH}, x_{relax}, x_{cook}, x_{eat}) = \left(1 + \frac{x_{PH}+1.66}{1.70} + \frac{x_{relax}+2.96}{2.97} + \frac{x_{cook}+1.66}{1.66} + \frac{x_{eat}+1.33}{1.33}\right)^{-1.11}$$

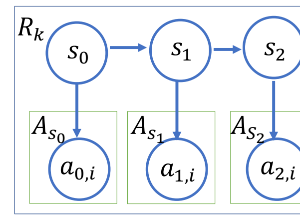
Markov Models of both Sequences of Activities and Loc

Selected Order for Different Datasets

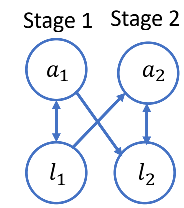
Group #	Groups	# of homes	activities with CPD	activities without CPD	locations	clusters with start/end	clusters w/o start/end
1	All	99	N/A	1	N/A	1	1
2	All Young	14	2	1	4	1	1
3	All Middle Aged	6	1	1	3	1	1
4	Middle Aged Single	4	1	1	3	1	1
5	Middle Aged Double	2	1	1	3	1	1
6	Middle Aged Not Healthy	1	1	1	2	1	1
7	Middle Aged Healthy	5	2	1	3	1	1
8	Middle and Old	3	1	1	3	1	1
9	All Old	53	3	1	4	1	1
10	Old Single	41	2	1	4	1	1
11	Old Double	12	2	1	3	1	1
12	Old Single Healthy	16	2	1	4	1	1
13	Old Single Not Healthy	17	2	1	4	1	1

Future Work

Hidden Markov Model



Our routine model generates a particular routine from a resident R_k by first generating a sequence of hidden states s_0, s_1, … according to a Markov model. Each state s_i then generates a list of activities $a_{0,i}$, $a_{1,i}$ … according learning from history data.



State transitions for routine models. Activities, a_i, and locations, l_1, are included in distinct states and routines progress through the stages in a fixed order.

A Model Combines Other Elements

Social interactions:

- Seniors whether or not keep the doors open
- Compare their health status

Time Spent in Locations:

- Duration models including parametric models, semiparametric models, nonparametric models

Conclusions

These findings will help researchers

- Understand indoor activity routine patterns
- Develop more sophisticated models of predicting routine behaviors and their timings
- Automate diagnoses
- Design customized behavioral interventions
- Provide activity-anticipatory services that will benefit both caregivers and patients.

Acknowledgements

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