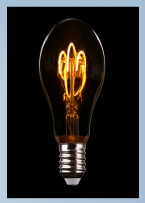
Human Behavior Modeling for Residential Energy Consumption

Mesfer Alrizq, Dr. Elise de Doncker

Department of Computer Science



ABSTRACT

Electric utility companies are interested in load profile (electricity consumption) data for expansion planning. Conventional methods of collecting the load profile data, such as surveys and metering, are tedious and time consuming activities. Cumbersome data collection processes also pose barriers. We present an innovative behavior model for generating electricity consumption load profiles. The model, based on fuzzy logic and activity graphs, requires minimum consumer data and can be easily updated to adapt to changes in technology. We demonstrate the accuracy of our model against real world data.

OBJECTIVE OF THE MODEL

- This eliminates the need for developing/distributing surveys by the utility company, and saves time and money spent for the surveys.
- The implementation focuses on modeling the relations between:
  - Environmental conditions, human behavior and energy consumption
- A fuzzy logic approach was used to develop the model.

DAILY ROUTINE OF PEOPLE

- Nathan Yau uses data provided by the American Time Use Survey from 2014 to demonstrate how people go through their daily routine [1].
- The daily behavior of 1000 people is demonstrated graphically in 30-minute intervals.
- Yau presents the behavior changes of US citizens, categorized according to age and gender [2].
- Six age categories have been considered: 15-24, 25-34, 35-44, 45-54, 55-64, and 65+.
- Each age category consists of two subcategories with respect to gender.
- Activity graphs were developed based on these data.

ACTIVITY GRAPH

- A sample activity graph in Fig 1 captures the major activities of males between ages 35 and 44 in their daily routine.
- Each activity is associated with a percentage value, which gives the probability of a corresponding activity.
- For example, there is a 59% probability that a person in this category is asleep at 6.00 am and there is 14% probability that he/she is doing work or a work-related activity.

1. Sleeping
2. Socializing/ relaxing / leisure
3. Personal Care
4. Traveling
5. Eating and Drinking
6. Work and Work-Related Activities
7. Phone Calls
8. Sports, Exercise, or Recreation
9. Household Activities
10. Shopping
11. Education
12. Religious and Spiritual Activities
13. Professional and Personal Care Services
14. Caring for Household Members
15. Volunteer Activities

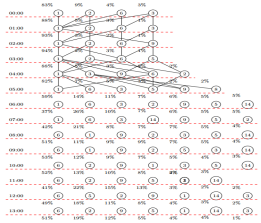


Figure 1: Activity graph of males between 35 and 44 years old

APPLIANCES USAGE DATA

- The US residential energy consumption survey (RECS) provides data on ownership and the usage of different appliances.
- From the appliance usage data and information on appliance usage in each activity, we can derive the probability of using a given appliance for a given activity by a person in a given age group.
- Similarly, we can calculate the probability of using different appliances for each activity in each age category.

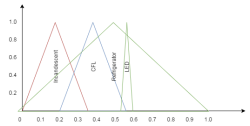


Figure 2: Fuzzy representation of base activities

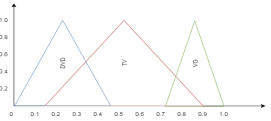


Figure 3: Fuzzy representation of socializing/relaxing activities

HUMAN BEHAVIOR MODEL

- The fuzzy logic based model was developed to model the human behavior changes, use of appliances and power demand.
- The rule-base in the fuzzy model is dynamic and influenced by the activity graph.
- The rule-base changes at each time instance to only incorporate the activities and corresponding appliances at that time instance.

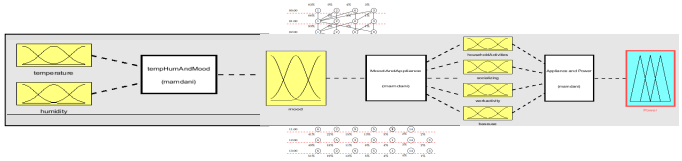


Figure 4: Human behavior model for demand prediction

FUZZY SYSTEM LAYERS

- The fuzzy system consists of three layers:
  - Environmental condition -> Mood
  - Mood -> Human activity
  - Human activity -> Power demand

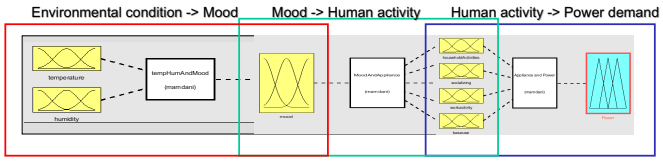


Figure 5: Layers of the fuzzy system

VALIDATION DATA SET

- The Irish CER Smart Metering Project – Electricity Customer Behavior Trial, 2009-2010 [3].
- 4232 Irish households over a period of 1.5 years (electricity consumption at 30-minute intervals and prior responded surveys).
- It was obtained by the Irish CER (Commission for Energy Regulation).
- It is distributed by the ISSDA (Irish Social Science Data Archive).

ACKNOWLEDGMENT

The authors would like to thank "CER Smart Metering Project - Electricity Customer Behaviour Trial, 2009-2010" for the data set that was accessed via the Irish Social Science Data Archive - www.ucd.ie/issda.

RESULTS

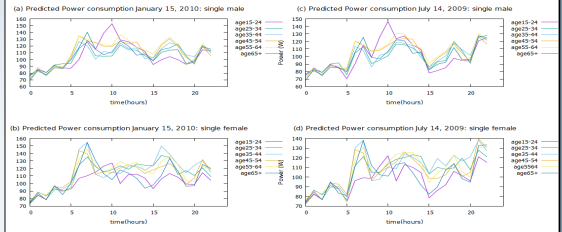


Figure 6: Comparison of 24-hour load profiles

Category	January 15, 2010	July 14, 2009
Male age 15-24	0.161	0.134
Male age 25-34	0.547	0.531
Male age 35-44	0.576	0.611
Male age 45-54	0.348	0.652
Male age 55-64	0.309	0.502
Male age 65+	0.411	0.557
Female age 15-24	0.287	0.298
Female age 25-34	0.581	0.597
Female age 35-44	0.534	0.662
Female age 45-54	0.298	0.614
Female age 55-64	0.376	0.550
Female age 65+	0.350	0.476

Table I

Correlation of the results with actual smart meter data for a single day

Category	Average correlation Winter 2010	Average correlation Summer 2009
Male age 15-24	0.104	0.249
Male age 25-34	0.345	0.562
Male age 35-44	0.334	0.500
Male age 45-54	0.691	0.436
Male age 55-64	0.336	0.568
Male age 65+	0.239	0.365
Female age 15-24	0.195	0.131
Female age 25-34	0.350	0.431
Female age 35-44	0.336	0.524
Female age 45-54	0.719	0.368
Female age 55-64	0.373	0.548
Female age 65+	0.222	0.425

Table II

Correlation of the results with actual smart meter data averaged over seasons

CONCLUSIONS

- We develop a novel method for predicting the load profile by using a human behavior model.
- Our model combines activity graphs and fuzzy logic theory to achieve more realistic load profiles that incorporate uncertainties.
- The comparisons shown in the Results section indicate a moderate to strong positive correlation between the simulated results and the smart metering data in [3] (moderate correlations are in the range 0.3-0.7; strong correlations are in the range 0.7-1).
- The advantages of our system are that it requires minimum consumer data and eliminates the tedious process of developing surveys, distributing them and analyzing the results.

BIBLIOGRAPHY

[1] Nathan Yau. A Day in the Life of Americans. url: https://flowingdata.com/2015/12/15/a-day-in-the-life-of-americans/

[2] Nathan Yau. Most Common Use of Time, By Age and Sex. url: https://flowingdata.com/2015/11/30/most-common-use-of-time-by-age-and-sex/

[3] Commission for Energy Regulation (CER), "CER Smart Metering Project - Electricity Customer Behaviour Trial, 2009-2010", 2012, 1st Edition. Irish Social Science Data Archive. SN: 0012-00, url: www.ucd.ie/issda/CER-electricity