

Poster Abstract: Generating Home Energy Footprint by Assigning Fixture Usage to Individuals in Homes

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Abstract

Homes and buildings are major consumers of energy across the globe. Since energy consumption in homes is largely dependent on the residents occupying it, encouraging home residents to engage in energy saving behavior has the potential to conserve significant percentage of total energy usage. It has been suggested that providing fine-grained energy usage feedback to residents, allows them to discover and engage in energy saving behavior. Home Energy Footprint (HEF) displays energy usage information for every individual at a appliance level granularity. We propose *fixture assignment* - assigning individuals to each fixture usage event, as a method to determine HEF.

Categories and Subject Descriptors

H.4 [Information Systems Applications]: Miscellaneous

General Terms

Energy Disaggregation, Energy Footprint

1 Introduction

Advances in science and technology have made people's lives in homes comfortable. There are appliances and gadgets to assist most aspects of domestic life. Consequently, homes use a lot of energy, accounting for 18% of the total world's energy consumption. Given the global scarcity of energy resources, this is a problem that needs to be remedied. Energy conservation has the potential to reduce 20-50% of a home's energy consumption. Residents can conserve energy by being conscious about switching off lights in empty rooms, reducing hot water usage during showers, etc. However, home residents often don't know how to conserve energy since they don't know where energy is being wasted. Utility bills, such as electric and water bills, provide only an aggregate level of feedback about the house's energy

consumption. If energy feedback is associated with individual energy usage actions, it will be easy for home residents to discover and gauge the impact of energy saving behaviors. Since, a home's overall energy usage is attributed to individuals' electrical and water fixtures usage, it has been hypothesized that a 'per appliance, per person' disaggregation of energy usage or *Home Energy Footprint*, would be effective for conservation [3].

2 Home Energy Footprint

A 'Home Energy Footprint (HEF)' is as inference of energy each person in a home uses, including a breakdown by individual electrical and water fixtures. As can be seen in Figure 1, disaggregating lights energy per person reveals where lights energy is wasted most and by which individual. Hay et al. [3] suggested that this easier and more detailed breakdown will produce enhanced and durable behavioral modification that results in long-term energy and water savings.

While there could be many different ways to determine HEF in homes, we focus on a method we refer to as *fixture assignment*. In this approach, we recognize that the total energy consumption in a home is composed of individual fixture usages' energy consumption. By identifying the individuals every time a fixture is used, we can assign the fixture usage event's energy to a person. In this way we can record and generate Home Energy Footprint for every individual in a home.

3 Fixture Assignment

Fixture assignment is the process of determining and assigning the individual responsible for a fixture usage event. There are different approaches to performing fixture assignments. We are currently exploring a couple different approaches for performing fixture assignments. One such approach tracks location of people, identifies the person located closest to a fixture when it is used, and assigns it to the person. The second approach uses gesture recognition using wearable devices to match an individual's actions to that needed to operate the fixture.

Using Gesture Recognition

In this approach, we use gesture recognition feature of wearable devices worn by home occupants to be able to perform fixture assignment. Various appliances in the home require interaction in different ways such as the push of a

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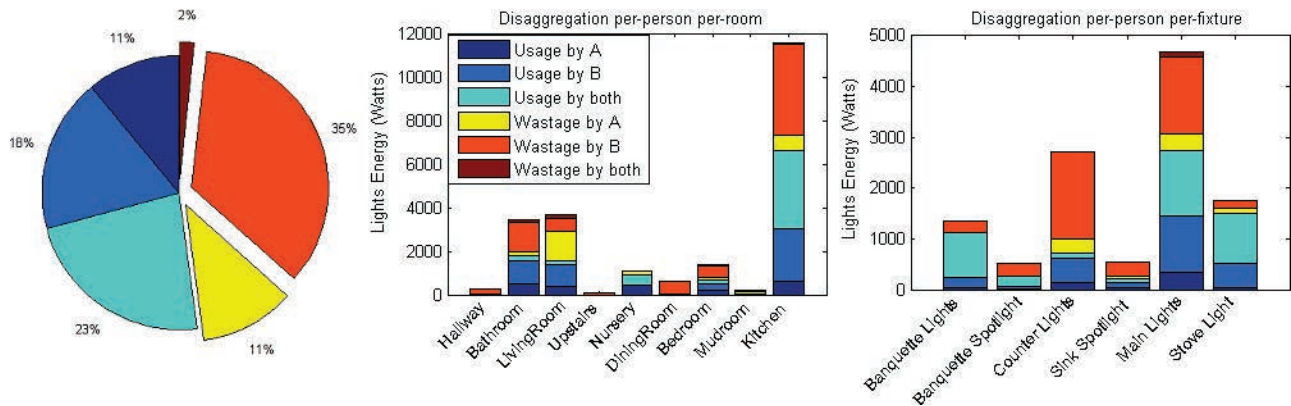


Figure 1. A case study of lights' energy: (a) Overall, person B wastes three times more energy than A, (b) Per person, per room disaggregation indicates that lights energy in Dining room and Hallway are mostly wasted, (c) Energy disaggregated per person, per fixture in the kitchen shows that the stove and banquet lights are used more efficiently

button, or turning a knob, etc. Each interface of an appliance results in an associated gesture, which can be learnt via the sensors attached to the wearable device worn by the person operating the appliance. When a fixture is used, the system searches the wearable devices of all the people present in the home, to find the person who would have made a gesture necessary to operate the appliance. The biggest challenge in this approach is that people can interact with the same appliance interface in many different ways. This can result in a variety of 'flavors' of the same gesture required to operate the appliance. Another challenge is that two people may perform similar gestures at the same time that an appliance is used. We are currently working on developing techniques to resolve these and other ambiguities.

Using Location Information

This approach to performing fixture assignment relies on being able to perform indoor localization of individuals in homes. The assumption here is that we have a model of the home's fixture identity and locations, as well as location information of residents in the home. We expect this assumption to be reasonable as currently there are systems in place that can determine which electrical appliances and water fixtures are being used by sensing only at single point [2, 1]. Not only can we determine the locations of electrical and water fixtures in homes [5], but we can also track people in homes non-intrusively at a room level, by instrumenting their doorways with height inferring sensors [4]. Given the information of where an electrical/water fixture is being used, and the knowledge of the occupant in closest vicinity to it, we can infer that the occupant is responsible for the electrical/water fixture usage.

This inference is simple when we know there is only one person in the room; however, when two or more people live together, there are often activities such as cooking, watching TV etc. in which multiple people are present in the room when an electrical/water fixture is used. This is the main challenge in performing fixture assignment using location information.

Using Past Fixture Usage Behavior

We could determine ambiguous fixture assignments by looking back in the unambiguous history of a fixture's usage events to determine the more probable user of the fixture. The use of different durations of look back in the history of a fixture's usage result in different accuracy numbers. This is because fixtures have different usage patterns. Some fixture usage patterns can be determined by the long term usage of it, such as stove. Other fixtures such as fridge may require monitoring more recent fixture assignments.

4 Conclusions and Future Work

Home Energy Footprint (HEF) displays energy usage information for every individual at a appliance level granularity. We explore a location based as well as gesture based fixture assignment method to determine HEF. In the location based approach, we develop a database of unambiguous fixture assignments, and use this history to determine who is using a fixture when multiple people are present in the same room. Our results indicate a variable performance for different look back durations in history, across different appliances and different groups of people for the same appliance. We intend to develop methods to determine the most appropriate look back duration to maximize fixture assignment accuracy.

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