Expressive, Tractable and Scalable Techniques for Modeling Activities of Daily Living

Don Patterson[1], Dieter Fox[1], Henry Kautz[1], and Matthai Philipose[2]

[1] University Of Washington,
Department of Computer Science and Engineering,
{djp3,fox,kautz}@cs.washington.edu
http://www.cs.washington.edu
[2] Intel Research
Seattle, WA USA
matthai@intel-research.net
http://seattleweb.intel-research.net/

One the best qualitative and quantitative tools that elder–care specialists have to monitor the health of elderly individuals is Activity of Daily Living (ADL) tracking [1, 2]. By watching the frequency and competency with which an individual can cook, clean the house, engage in socializing, etc, short– and long– term changes in health can be identified. This talk will present efforts underway at the University of Washington [3–5] and Intel Research Seattle [6] to mitigate the economic and social costs of aging by automatically recording a journal of ADL activity.

Our approach is based on Radio Frequency Identification (RFID) tags which resemble two inch by two inch paper stickers. There is no power supply associated with an RFID tag, but when a special antenna broadcasts an information request, the tag collects the energy from the request and re-broadcasts a uniquely identifying number that is embedded within it. The querying antenna listens for the id numbers of any tags which respond and processes the information. Versions of this technology are familiar from their use in retail anti-shopping-lifting systems. Many consumer goods manufactures have begun to experiment with permanently embedding these tags in retail items such as razors and designer clothing in an effort to streamline supply chain management. Our ADL journaling research is a novel use of the tags once they are in the home environment.

Intel Research [6] has developed an antenna embedded in a glove which is able to see all tags that are located within three inches of the palm of the wearer. This closely approximates sensing when an object is touched. This device is compelling because it does not require external infrastructure, has a small form factor and effectively guards user privacy with a single point of information control. Our research hypothesis is that an appropriately developed user model can infer the current activity of the wearer from a sequence of RFID tag readings.

Our approach fundamentally depends on developing a model which is expressive, tractable and scalable. We desire our activity models to be expressive so that they are human understandable and describe an intuitive understanding of an "activity." At the same time, the model must be tractable so that tracking user activities can be done in real-time by an off-the-shelf computer. Finally, the

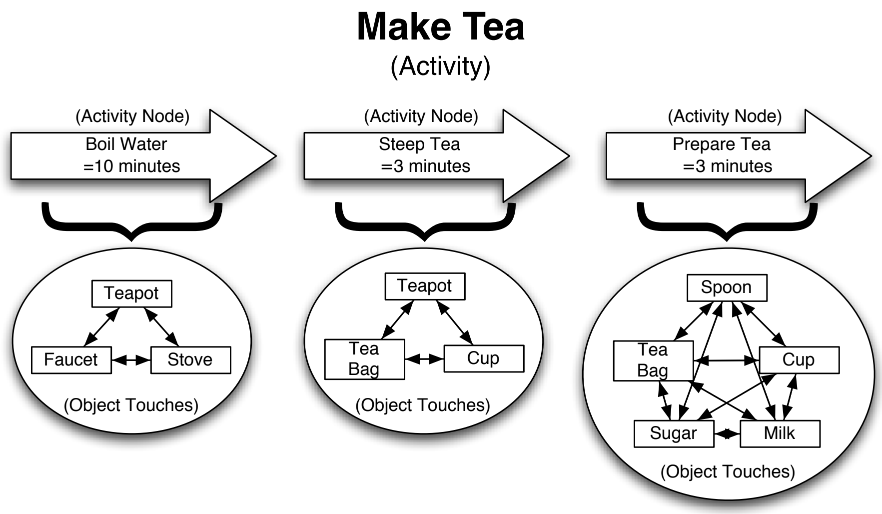

Fig. 1. Visualization of an Activity Model

scope of our vision (which extends to tracking more activities than just ADLs) requires that the models be scalable. They must be able to accommodate a full range of consumer goods and hundreds or thousands of activities, and as such we require that the models can be computer generated.

To meet these constraints, we have developed an activity model which describes an activity as a sequence of "bags of touched objects" (see Fig. 1). More formally we describe the model as follows: Let R_i indicate that object i has been touched. Let $D(\mu, \sigma)$ be a Gaussian distribution over a time duration which describes the expected amount of time over which all the objects will be touched. An activity node, a (e.g. boil water), is an unordered set of object touches (e.g. teapot, faucet, stove) paired with an expected duration: $a = [\{R_{a_1} \ldots R_{a_n}\}, D_a]$. A full activity, A (e.g. make tea), is an ordered sequence of activity nodes: $A =< a_1, \ldots, a_k >$.

A full activity's expected time distribution is the sum of the distributions of the activity nodes which it contains: $D_A = \sum_{i=1}^{k} D_{a_i}$.

Our activity model closely mirrors the structure of a recipe with several ordered steps each of which is individually loosely structured. As such, we generate our models by mining activity and recipe web sites [7].

Once our models are built we translate them into a Dynamic Bayesian Network. We have custom built an inference engine which uses the models and the data stream from the RFID glove to track user activities. The inference engine uses a particle filter based method to approximate finding the solution to the maximally likely sequence of states given the observations. A user's ADL journal can then be generated from this sequence of states.

We have promising preliminary results based on simulated data, as well as results from real data taken from 10 people performing ADLs in a tagged home.

Using extensions to work on Voronoi graph tracking [8] that we developed in the context of transportation tracking [9], we anticipate being able to learn better activity models as well as idiosyncratic patterns of particular activities that a user exhibits.

1 Author's Biographies

– *Donald J. Patterson* is a Ph.D. candidate in the Computer Science Department at the University of Washington. He graduated from Cornell University with a B.S. in Computer Science and an M.Eng. in Electrical Engineering. After spending a few years in the military, he returned to academia as an NDSEG fellow and is currently researching artificial intelligence and its application to health care through the Assisted Cognition Project. He is spending the summer working on ubiquitous computing applications at Intel Research Seattle.
– *Dieter Fox* is an Assistant Professor in the Department of Computer Science and Engineering at the University of Washington. He joined the faculty in the fall of 2000. He grew up in Bonn, Germany, and received a B.Sc. in 1990, an M.Sc. in 1993, and a Ph.D. in 1998, all from the computer science department at the University of Bonn. Before going to UW, he spent two years as a Postdoc in CMU's robot learning lab. Dieter Fox heads the AI-based mobile robotics lab which he established in January 2000.
  His research interests lie in artificial intelligence and its application to mobile robotics. More recently, he and colleagues introduced particle filters as a powerful tool for state estimation in mobile robotics.
– *Henry Kautz* is an Associate Professor in the Department of Computer Science and Engineering at the University of Washington. He joined the faculty in the summer of the year 2000 after a career at Bell Labs and AT&T Laboratories, where he was Head of the AI Principles Research Department. His academic degrees include an A.B. in mathematics from Cornell University, an M.A. in Creative Writing from the Johns Hopkins University, an M.Sc. in Computer Science from the University of Toronto, and a Ph.D. in computer science from the University of Rochester. He is a recipient of the Computers and Thought Award from the International Joint Conference on Artificial Intelligence and a Fellow of the American Association for Artificial Intelligence . In 1998 he was elected to the Executive Council of AAAI, and in 2000 was Program Chair for the AAAI National Conference.
– *Matthai Philipose* is a researcher at Intel Research Seattle. His chief interest is in making ubiquitous computing systems useful and practical. Currently, he co-leads the Guide project (which is devoted to acquiring and understanding RFID data), and leads the River project (which is devoted to understanding how to make ubiquitous computing systems easier to manage). He did his graduate work at the University of Washington, and his undergraduate work at Cornell University.

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