Augmenting Kitchen Appliances with a Shared Context using Knowledge about Daily Events

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ABSTRACT
Networked appliances might make them aware of each other, but interacting with a complex network can be difficult in itself. KitchenSense is a sensor rich networked kitchen research platform that uses Common Sense reasoning to simplify control interfaces and augment interaction. The system's sensor net attempts to interpret people's intentions to create fail-soft support for safe, efficient and aesthetic activity. By considering embedded sensor data together with daily-event knowledge, a centrally-controlled system can develop a shared context across various appliances. The system is a research platform that is used to evaluate augmented intelligent support of work scenarios in physical spaces.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Interaction styles. D.2.2 [**Design Tools and Techniques**]: User Interfaces. J.7 [**Computers in other systems**]: Consumer products. I.2.2 [**Artificial Intelligence**]: Programming Languages and Software- *Expert system tools and techniques.*

General Terms
Algorithms, Design, Experimentation.

Keywords
Commonsense reasoning, Intelligent Environments, Home Appliances, Shared Context, Daily Events, Kitchen.

1. INTRODUCTION
Kitchen appliances have so many built-in functions that they can be difficult to control for simple tasks. What if the appliances could understand what you need, and encourage you to succeed at that? This paper presents kitchen appliances that are networked with a series of embedded sensors and a central common-sense database to understand their context and offer useful and relevant interface options.

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Intelligent environments usually model situations to improve user experience. They have the potential of transforming a physical space into a responsive computer. Most appliances at home already contain sophisticated sensors, displays, actuators and computer controls. If these sensors are integrated into a knowledge-based network, the appliances may be able to better understand human behavior [1]. Investing physical spaces with intelligence can make an informative physical space less distractive, while enhancing the efficiency of tasks [2]. Context-aware design observes human behavior to understand intention and offer functional aid [3]. Easy-to-associate information retrieval and fail-soft recommendations make intelligent interfaces more reasonable to people [4]. Human commonsense can help machine to avoid some common mistakes and optimize human understanding ways of problem-solving [5].

Figure 1. Kitchen appliances are augmented with KitchenSense and attentive displays.

This paper presents KitchenSense, a kitchen event management system with embedded sensors on home appliances and centralized knowledge about daily events. KitchenSense is the back-end system of the Augmented Reality Kitchen workspace [6] which consists of immersive intuitive displays (see Fig. 1) projected on the surfaces of the space. A network of proximity, temperature, and pressure sensors is used to create a model of what people are doing in the kitchen. KitchenSense annotates sensor inputs with the most probable human activity to create mappings for attentive displays to augment kitchen events. Pilot Studies of KitchenSense were performed in order to build the CommonSense database, and would have to be expanded in further applications. KitchenSense demonstrates that home appliances equipped with enough knowledge about daily events can be more easy and productive to use.

2. SHARED CONTEXT SCENARIOS

Digital home appliances often provide an excessive number of functions. One way of improving interaction is to make redundant functions disappear when we don't need them. Networked appliances provide opportunities for understanding an overall situation from multimodal sensor inputs. In a kitchen, office or lab, people often use several appliances together or in sequence. The kitchen is also the most dangerous space in the home and a good place to test whether common sense improving real world scenarios. Making appliances *understand* what a person or other parts of the kitchen are doing might encourage the user aware of the overall environment or smooth the working process across various devices. KitchenSense creates a shared context to create auxiliary controls and information that might streamline human requirements for perception and action .

KitchenSense networks appliances and sensors under a central common sense database to create a shared knowledge-base. Individual appliance interfaces change based on how the kitchen is being used. KitchenSense finds out the goals based on what the users did and provides relevant functions for related kitchen events.

Figure 2. When a user opens the fridge and stands in front of the microwave, the kitchen recommends an enhanced microwave interface for him to 'cook' or 'reheat' food.

In one example, someone opens the refrigerator to take out a piece of cold pizza and walks to the microwave oven. A micro-switch on the refrigerator senses that the door is open, and a proximity sensor on the microwave detects that someone is standing in front of it. The system infers that when a person uses the fridge and then stands in front of the microwave, he/she has a high probability of re-heating food (see Fig. 2). the microwave control panel provides the "reheat" function predominantly on digital projected control panel near the microwave.

Similar groupings of tasks from around the kitchen can be used to make simpler control interfaces on the individual appliances. For example, the dishwasher would likely only be able to be turned on if it contains dirty dishes. The cook-top can provide temperature controls based on the surface temperature of pans on the range. Next, KitchenSense can enhance and augment cooking activities. When someone is cooking, the system can suggest where to find ingredients and appliances or even propose new techniques or recipes. Appliances can furnish more information about themselves if someone stands in front of them or operates them erratically. KitchenSense can also be used to promote certain behaviors, such as hygiene and energy conservation by varying interaction based on where people are and what they are doing.

3. KITCHENSENSE ARCHITECTURE

KitchenSense is a back-end software and hardware infrastructure to augment appliances in a domestic kitchen with machine intelligence (see Figure 3). KitchenSense takes the cooking and kitchen part of OpenMind Commonsense [5] and interfaces it with sensors on the cabinets, range, fridge, recipe and sink of a conventional kitchen. Together with immersive displays projected onto the augmented appliances, KitchenSense attempts to infer user's intention with commonsense and provide visual feedback based on what they did before. KitchenSense is able to simplify the user interface of home appliances, motivate the user to be aware of concurrent tasks, and help develop productive habits.

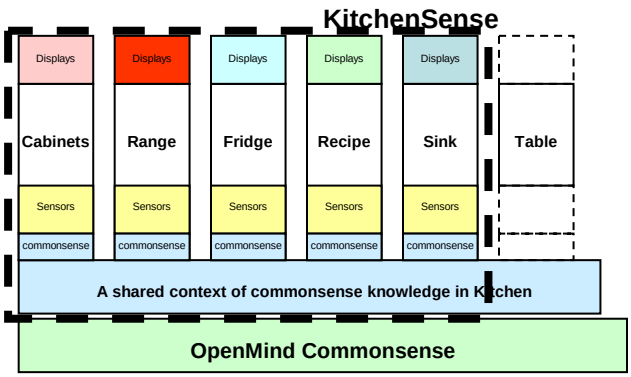

Figure 3. KitchenSense Architecture.

KitchenSense consists of input sensors, output projections and a kitchen event reasoning engine. Input sensors monitor the position of people and the status of appliances and cabinets. Output projections are digitally-augmented projections which mediate people's attention through seamless projected graphics on the surfaces of the space. A kitchen event reasoning engine uses OpenMind and ConceptNet [7] to categorize and understand human behavior.

3.1 Commonsense Inference Engine

KitchenSense is a kitchen-related daily knowledge subset of OpenMind: a verbal database containing over 700,000 utterances about everyday life. The OpenMind database contains sentences describing common sense facts. Kitchensense uses concepts about kitchen activities and dangers as well as hints and recipes. These facts are compared to statements created for KitchenSense based on sensor data. KitchenSense connects concepts based on their probability of being related based on how similar their verbal descriptions are. For example, the Augmented Refrigerator recognizes the proximity sensor as "I walk to the fridge" and the micro-switches are annotated as "I open the refrigerator" or "I open the freezer" in order to trigger related events.

KitchenSense seeks to infer what will be useful or productive to the user through a Goal-Oriented Interface [8], so that when a person opens the freezer and goes to the microwave, KitchenSense decides he probably wants to defrost food. The system constantly infers causal and temporal relationship of

events by using spreading activation algorithm (see Fig 4.) Events are decomposed into a directed graph of action nodes. Each action node is linked to one another based on the probability of the action that might occur next. Spreading activation of semantic association is used for injecting energy to certain nodes and checking if some nodes are activated under such situations. The ConceptNet database tell us that 'people get hurt by hot water' and 'the kitchen is a dangerous place for children.' KitchenSense associates 'hot water' and 'child' with 'danger.' When a child approaches a pot of boiling water, the Augmented Reality Kitchen flickers the lights and play an audiovisual animation. KitchenSense offers a safety monitor, an augmented recipe and persuasive reminders.

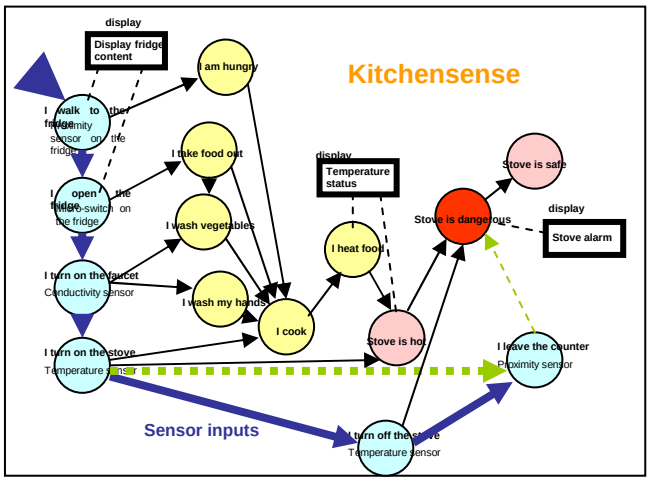

Figure 4. Spreading activation for the kitchen event network.

4. EXPERIMENT

We conducted an experiment to study the capability of the KitchenSense system. The goal of this study was to capture events and add knowledge to the processes of using the kitchen for preparing and cooking food.

4.1 Experimental Setup

Experimental Platform and Display

KitchenSense was installed as the back-end system of the Augmented Reality Kitchen project. KitchenSense manages various kinds of sensor inputs from the augmented appliances and uses commonsense inference engine to find out recommendations like instructional indicators or ambient displays for current kitchen activities. KitchenSense interprets sensor inputs as the current actions and makes inference for possible next actions and guess subject's intention. To develop the verbal database for KitchenSense, a pilot study during which investigators correlated sensors readings with actual tasks. 5 people 18-38 familiar with cooking in these kitchens were asked to prepare a meal in the kitchen. Ideally, a system like KitchenSense would continually learn from the actions of people in a given space.

4.2 Experimental Results and Discussion

The technical evaluation of KitchenSense revealed a wealth of information that could associate sensor inputs with cooking actions in the verbal database. For example, the microwave develops three types of associations:

Microwave:

Open the freezer -> walk to the microwave -> defrosts meat
Open the fridge -> walk to the microwave -> reheat leftover
Open the faucet + open the cabinet (for a cup) -> boil water

Interpreting sensor inputs as simple events is useful for commonsense reasoning. Finding suitable interpretations of sensor inputs is useful for expending or limiting the spreading activation of the commonsense semantic network. For example, before the study, "I am in the stove zone" was used to indicate someone approaching the stove. After the study, it was changed to "I use the stove" to get better inferences of "use the stove".

This study considerably increases the database of KitchenSense. Nevertheless, more sensing and learning would be desirable in a product, perhaps through continual adaptation of the system. The KitchenSense architecture is modular and extensible so that more knowledge and appliances can be added to the system.

5. DISCUSSION

Modern spaces full of appliances can be easier and more productive to interact with if the various machines are aware of a user's behavior and have some understanding of common actions. By combining a CommonSense database and probability engine in a real-world networked kitchen, KitchenSense demonstrates applications made possible by intelligent environments. Interfaces can be simpler, the environment can be safer, and people can learn about new activities and behaviors more easily.

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