

# Aware homes

Marco Aiello

*The Smart Homes for All project has shown that 'aware' homes with up-to-date contextual information can successfully react to the state of their inhabitants.*

The movie *Kitchen Stories* (2003), set in rural Norway in the 1950s, portrays a Swedish researcher sitting on a raised chair in the kitchen of a farmer, observing how the space and appliances are used.<sup>1</sup> The observer has a map on which he records all the movements and activities of the homeowner. The final goal of this ethnographic study is to collect enough observations to deduce how kitchens are used in practice and what can be improved in the design of the next generation of Swedish furniture. The movie, which builds on the tension between the observer and the observed, carries an interesting idea from industrial design: the user and the usage should be the driver for creating ergonomic spaces, and usage is best observed in situ. The idea is still pursued today, with the advantage that we are able to observe unobtrusively and automatically. Sensors and communication technologies allow us to automate data acquisition, while making it more reliable and information-rich. At the same time, we gain the possibility of real-time adaptation of the environment to the needs of the inhabitant.

A number of sensors are able to measure physical quantities and can be used to infer information about the user and the home situation. The context of the home is its state at any given moment. The context includes facts about the users (location and activity currently being carried out), the appliances (refrigerator temperature and content, instantaneous electricity consumption of any device connected to a socket), the spaces (room temperature, status of heaters and coolers, status of doors and windows in terms of being open, closed or locked) and the home situation (weather information, cost of electricity on the grid). A modern home can in this way be aware of its state and that of its inhabitants. But moving from simple sensor reading to complex contextual information, such as inhabitant activity, is still a challenge. Huebscher and McCann (2004) proposed context-aware middleware to support access to home context information.<sup>2</sup> Contextual information is central to the creation of an architecture for a smart home. The initial state of the home and of its inhabitants is fundamental for the system to decide how to actuate/operate/act/execute in the home and, in turn, satisfy the needs of the user. But context alone makes the home aware, not



**Figure 1.** A visualization of the smart home used in the Smart Homes for All project, created for simulation purposes.

smart. Some authors have questioned whether this is desirable. Some advocate simply giving back the contextual information to the user so that he or she can make informed decisions.<sup>3</sup> We take the opposite tack.

In the European project Smart Homes for All (SM4All), we have designed an architecture to go beyond awareness and introduce the concept of a proactive home (see Figure 1). We base our system on the abstraction of a service providing for an open, dynamic and flexible sensing and control infrastructure. We consider any digitally enabled object as a service provider and consumer (sensors, appliances, lights, doors, windows and so forth) and interpose a composition layer between the user and the home services. The composition layer is responsible for abstracting the context, coming up with smart decisions and translating these into service calls.

The composition module receives high-level complex goals issued either by the user (e.g., a request for a beer) or the home itself (e.g., an emergency goal for combating some dangerous gas that has been detected in the kitchen), and tries to fulfil them by generating appropriate compositions of the available services. The compositions are computed on the fly by a domain-independent planner which uses constraint satisfaction

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techniques, based on the current home domain delivered by the repository and the state of the environment provided by the context-awareness module.<sup>4</sup> Whenever a goal is issued, the planner generates a plan: a sequence of service operations (actions), the execution of which changes the state of the environment in accordance with the properties prescribed by the goal. The plan is then passed to an orchestrator, which translates the composition into lower-level service invocations and executes them step by step. In the case where a service operation returns a permanent failure, the plan execution is terminated, and the composition module is asked to compute a new alternative plan for the same goal. The erroneous service is removed from the registry of currently active devices.

We tested the SM4All architecture in a laboratory home on the premises of the Santa Lucia Hospital in Rome, and our results show the viability of the approach. More than 50 sensors and actuators were coordinated in order to satisfy medical and comfort goals of users with diverse needs.

Our tests verified the availability of up-to-date contextual home information. The home successfully monitored and reacted to the state of its inhabitant and its components. The house was aware of the location of the inhabitant, whether a door was closed or open, and whether a bed was occupied. It was even aware of the contents of the refrigerator. The home was also able to respond to the desires of the occupant. A number of test scenarios triggered by occupant goals ran successfully in the home, and the success of the runs was independent of the initial state and changing conditions. For example, if a connecting door was locked during execution, an alternative path was suggested when available. If a light did not turn on because of a failure, an alternative light source would be sought and lit.

The current focus of our research is to tailor the automation of indoor spaces to the reduction of energy consumption while unobtrusively maintaining the comfort and productivity level of the inhabitants intact.

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## References

1. <http://www.imdb.com/title/tt0323872/> *Kitchen Stories* (2003) is a movie set in rural Norway in the 1950s.
2. M. C. Huebscher and J. A. McCann, *Adaptive middleware for context-aware applications in smart-homes*, **Proc. MPAC**, pp. 111–116, 2004.
3. S. S. Intille, *The goal: smart people, not smart homes*, **Proc. ICOST**, 2006.
4. E. Kaldeli, E. Warriach, A. Lazovik, and M. Aiello, *Coordinating the web of services for a smart home*, **ACM Trans. Web** 7 (2), p. 10, 2013.