About Composing Our Own Smart Home

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ABSTRACT
This paper reports on an empirical study designed as a follow-up of a theoretical model intended to support reasoning about the composition of smart artifacts by end users. We have solicited 17 families and used a combination of interviews and playful cultural probes. Results show that families are willing to couple smart objects to improve their lives, and that the theoretical questions raised by our model are sound.

Categories and Subject Descriptors
D.2.2 [**Software Engineering**]: Design Tools and Techniques – *User interfaces.*

General Terms
Design, Experimentation, Human Factors.

Keywords
End-User composition, smart artifacts coupling, smart home, ubiquitous computing, service-oriented computing.

1. INTRODUCTION
Ubiquitous computing promises unprecedented empowerment from the flexible and robust combination of software services with the physical world. Software researchers assimilate this promise as system autonomy where users are "conveniently" kept out of the loop. Their hypothesis is that services, such as music playback and calendars, are developed by service providers and pre-assembled by software designers to form new service front-ends. Their scientific challenge is then to develop secure, multi-scale, multi-layered, virtualized infrastructures that guarantee service front-end continuity. Although service continuity is desirable in many circumstances, end users, with this interpretation of ubiquitous computing, are doomed to behave as mere consumers, just like with conventional desktop computing.

Another interpretation of the promises of ubiquitous computing, is the empowerment of end users with tools that allow them to create and reshape their own interactive spaces. The mashup paradigm incarnates this view for networked knowledge and services. Mashups, however, are concerned with the digital dimension of our world, not with the combination of the digital with the physical. In this paper, we focus on the composition of smart artifacts by end users, bringing together physicality and digital power. Examples of such artifacts include smart phones, augmented fridges, or information appliances.

Our hypothesis is that end users are willing to shape their own interactive spaces by coupling smart artifacts, building imaginative new functionalities that were not anticipated by system designers. A number of tools and techniques have been developed to support this view including the Jigsaw editor [5], CAMP [8], iCAP [4], or Newman's work on end user composition with OSCAR [6]. The major focus of this prior work is on exploring novel interaction techniques and on technical frameworks. In this paper, we are concerned with the fundamental meaning (and human needs) of building confederation of interoperating smart artifacts.

In [2], we present a chemistry-inspired theoretical model that supports reasoning about the composition of smart artifacts by end users. Whereas scientific knowledge in chemistry is sufficiently advanced to predict the occurrence and results of a reaction, such knowledge is clearly lacking in ubiquitous computing. In particular, we are unable to predict which artifacts of every day life end users would be willing to couple (and decouple) to obtain new services. Is coupling commutative, associative, distributive over some other operation? In other word, can we define an algebra over smart artifacts so that we can generalize the problem and reason at a high level of abstraction in a rigorous manner?

The field study presented in this paper is our first attempt at answering the questions raised by our theoretical model. The experimental study is presented in the next section. Our findings are discussed in the last section.

2. THE EXPERIMENTAL STUDY
2.1 Participants
Drawing on Davidoff's et al. experiment and conclusions (i.e. "families want more control of their lives" [4]), we focused on "busy" families. The participants have been solicited through bulletin board advertisements, email, as well as from personal relationships.

We have recruited 17 families representing a total of 40 persons (35 adults and 5 children), all living in the area of Grenoble (France). Of the 17 families, 12 were dual income families, 1 was single parent, 2 were house mates, and 2 were retired couples. All families were well educated with medium to high standard of living.

2.2 Method

Our method was designed to reconcile the following requirements: to collect meaningful data in a minimum of time while respecting privacy. As presented above, we are interested in determining how far people are ready to envision the interconnection of everyday devices to improve control of their lives, and to which extent coupling objects is commutative, associative and distributive. For so doing, we have used a combination of interview [7] (good for clarification), playful cultural probe (appropriate for respecting privacy and for improving subjects involvement [1]). The presence of the experimental team (ourselves, from 1 to 3 persons) was limited to 1h30 per family home. Fieldwork was structured as a four-step process: photographing, interview, game, and debriefing.

Step 1: Photographing. Using digital cameras provided by the experimental team, two volunteer family members were asked to take pictures of 10 objects at the rate of 2 objects per room. For each of the 5 rooms of their choice, they were asked to take the picture of one object that they considered to be necessary in their every day life or that would help them in organizing their lives, as well as the picture of one object that they considered to be superfluous but valuable (typically, a painting). The volunteers (in general, the parents) were not supposed to be in the same room at the same time so that they would not know which pictures the other member had taken. Meanwhile, the experimental team would wait sitting at a place indicated by the parents (typically, the living room where they usually meet with friends and visitors).

Step 2: Interview. We then conducted an interview with all the family members, using the pictures as input material. Questions were directed at understanding the reasons for their choices, the value attached to the objects or the services provided in daily use. Special attention was given to the (many) remote controller(s) typically found in the household environment. We progressively oriented our questions towards novel uses of smart artifacts. In particular, we asked which objects of the house (including those on the pictures) they would qualify as "programmable" (e.g., TV's, washing machines, alarm clocks), "communicating" (e.g., computers, mobile phones), or emotional (i.e. carrying intimate value). This was used as a means to elicit routines and exceptional needs as well as to prepare the game developed in Step 3.

Step 3: Association game. The association game drew on people creativity using the pictures as play cards. Pictures were sorted randomly and presented two at a time (then, three at a time) on a tablet PC. Family members were asked to imagine which service(s) and value(s) these two (or three) objects coupled together would provide them with. Random coupling was designed to solicit imagination in unexpected ways, and to get hints about the existence of a "natural" algebra over smart artifacts.

Step 4. Debriefing and informal discussion. The last stage was dedicated to debriefing, including opened friendly discussions.

Overall, we have collected comments and objective data for 349 couplings for a total duration of 25 hours of our presence in the 17 family homes.

2.3 Data Analysis

Interviews and debriefings helped us to identify recurring facts between home families such as key moments during weekdays for which families would expect support from a smart home, or attitudes with regard to "programming the home". Data from the association game as well as from the interviews were used to find answers to our theoretical questions. More specifically, we classified the objects that have been photographed into four categories: objects that have been denoted as "programmable" by the subjects, objects that have been declared as "communicating", objects that support both capabilities, and objects that have none of these two properties. Using the Chi-square test, we have been able to find strong significance between the abilities of the subjects to envision (or not) services depending on the capabilities of the assembled objects. In particular, the communication capability allows peoples to more easily imagine new services from the assembled object.

3. FINDINGS

Our experiment has led to three types of results: recurring facts across families, early answers to our theoretical questions, as well as insights about our method.

3.1 Recurring Facts

We found a number of facts that are quite consistent with the results reported in prior literature:

1. "Wake-up" time, "on-the-way-to-home" and "arriving-home" times are key to people. To save time and improve efficiency, activities are organized into well-polished procedures. As a result, exceptions to these routine tasks are sources of stress. Support for avoiding or for solving exceptions is one class of services expected from a smart home. This includes the management of possessions (laundry to be launched because of a business trip planned in a couple of days, food on the point to be missing, medicine close to expiration date), decision-making (what to buy, what to wear today), reminders (doctor appointment), security (door properly locked), resources consumption and resource sharing among family members (typically, hot water and bathroom occupation in the morning), etc.
2. With regard to programming, attitudes range from "I do not want to be assisted" to "It will work 99% of the time, but it will be hell for the other 1%". Motivation for programming is systematically grounded on a clear straight forward observable benefit.

We believe that our findings related to coupling everyday life objects are original.

3.2 About Coupling

Our data from the association game shows two important results: (1) Family members are prone to envision new services when coupling involves one "communicating" object, or one "programmable" object, at least. (2) The "communicating" capability has more impact than "programmability" on the capacity of family members to imagine new services. However, 78 of the 349 couplings resulted in service finding although none of the objects were programmable or communicating. For example, the couple "bed-shower", whose objects had not been classified as programmable nor communicating, suggested that "getting up from the bed in the morning would turn the shower on in order to provide water at the right temperature when coming back from the toilet". This means that there is a large body of potentiality for novel services based on mundane everyday objects[1].

The services suggested by our family members fall into four categories. We illustrate them with the most typical examples drawn from our fieldwork.

Service substitution. People have observed that, for the same (sport) events, commentaries on radio broadcasts are richer than those provided by TV. As a result, they would like to replace the TV sound service with that of the radio to improve the overall quality of the informational experience. Another example is User Interface substitution: some people are quite skill at setting up alarms on their mobile phone, but they do not know how to do this for their physical home alarm clock. As a consequence, they would find it quite convenient to replace the user interface of their alarm clock with that of their phone thanks to a convenient opportunistic coupling of the phone with the alarm clock.

Service improvement. Some household appliances such as washing machines and cubboards, do not provide any convenient way to control and monitor their current internal state. Appliances than are not sufficiently equipped could be improved by coupling them with additional input and output facilities such as those of the TV set.

Service chaining. Service chaining is intended to improve comfort, wellbeing as well as resources for the routine, but hectic, activities. For example, "picking up the towel after the shower would trigger the coffee machine so that coffee would be ready just in time, at the right temperature, along with the radio turned on in the kitchen broadcasting the news using the appropriate sound level".

Service "starter". We have observed that some appliances serve as triggers for services that are expected to be pre-composed to support routine activities. The towel and the bed mentioned above, play this role, implicitly. Not surprisingly, people also want to have an explicit and reliable control over the home (cf. the worry that 1% of the time, the house would turn into hell). Some people came up with the "*morning starter push button*" conveniently located close to the bed that would gently "wake up" the house when pushed.

The need for chains of services underpins some form of associativity. For example, one family qualified the "towel-coffee machine" coupling as a "morning package". If the expression *towel – coffee* denotes the coupling of the towel with the coffee machine, then *(towell – coffee)*, between parenthesis, denotes the notion of package. During the discussion, our family members thought of adding the "morning starter push button" b to get a controllable chain "$b – t – c$". Here, their mental construction can be formalized as a right associativity of the "coupling" operation: $b – t – c = b – (t – c)$.

Coupling for service improvement entails some form of distributivity. Typically, the TV set *tv* has often be mentioned as a way to observe and control the state of a number of appliances such as the washing machine w or the oven o. This can be formalized in the following way: $tv – (w \mid o) = tv – w \mid tv – o$. Commutativity is generally satisfied with notable exceptions when there is a causality relationships between the objects.

[1] Detailed quantitative data will be presented in a full paper.

3.3 About the Experimental Method

The "Snapshots taking" of our fieldwork has multiple advantages: (1) It serves as an ice breaking between the family members and the experimental team; (2) Family members "reveal their house" naturally while we, the experimenters, do not intrude their private spots. (3) Family members get truly involved (and intrigued by what will come next). (4) As opposed to playful probing proposed by R. Berhaupt [1], our game uses images of intimate objects, not of generic entities. This increases the interest and imagination of the participants while improving the meaningfulness of the data collected.

4. CONCLUSION

A central focus of our work is investigating the fundamental meaning of building confederation of interoperating smart artifacts. Our approach to this problem is theory-driven with the quest for an algebra that would support generalization and prediction. Although additional investigations are necessary, early results from our fieldwork support this approach.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Bernhaupt, R., Weiss, A., Obrist, M. & Tscheligi, M. (2007) Playful Probing: Making Probing more Fun. In *INTERACT 2007*, Springer LNCS, 606-619.

[2] Coutaz, J. (2008) End-User Programming and the Intrinsic Complexity of Networked Artefacts. In *4th Workshop on End-User Software Engineering*, ICSE 2008.

[3] Davidoff, S., Lee, M.K., Yiu, C. Zimmerman, J. & Dey, A. (2006) Principles of Smart Home Control. In *Ubicomp 2006*, LNCS 4206, Springer Verlag Berlin Heidelberg, 19-34.

[4] Dey, A., Sohn, T., Streng, S. & Kodama, J. (2006) iCAP: Interactive prototyping of context-aware applications. In Pervasive 2006, Springer, 254-271.

[5] Humble, J., Crabtree, A., Hemmings, T., Akesson, K.P., Koleva, B., Rodden, T. & Hansson, P. (2003) "Playing with the bits" user-configuration of ubiquitous domestic environments. In *Ubicomp 2003*, 256–263.

[6] Newman, M.W., Elliott, A. & Smith, T.F. (2008) Providing an integrated user experience of networked media, devices, and services through end-user composition. In *Pervasive 2008*, Springer Verlag, 213–227.

[7] Silverman, D. (1997). Introducing qualitative research. In D. Silverman (Ed.), Qualitative research. Theory, method and practice London:Sage, 1-7.

[8] Truong, K.N., Huang, E.M. & Abowd, G. (2004) CAMP: A Magnetic Poetry Interface for End-User Programming of Capture Applications for the Home. In Ubicomp 2004, Springer, 143-160.

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