What Would You Ask to Your Home if It Were Intelligent? Exploring User Expectations about Next-Generation Homes

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What Would You Ask to Your Home if It Were Intelligent? Exploring User Expectations about Next-Generation Homes

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Abstract. Ambient Intelligence (AmI) research is giving birth to a multitude of futuristic home scenarios and applications; however a clear discrepancy between current installations and research-level designs can be easily noticed. Whether this gap is due to the natural distance between research and engineered applications or to mismatching of needs and solutions remains to be understood. This paper discusses the results of a survey about user expectations with respect to intelligent homes. Starting from a very simple and open question about what users would ask to their intelligent homes, we derived user perceptions about what intelligent homes can do, and we analyzed to what extent current research solutions, as well as commercially available systems, address these emerging needs. Interestingly, most user concerns about smart homes involve comfort and household tasks and most of them can be currently addressed by existing commercial systems, or by suitable combinations of them. A clear trend emerges from the poll findings: the technical gap between user expectations and current solutions is actually narrower and easier to bridge than it may appear, but users perceive this gap as wide and limiting, thus requiring the AmI community to establish a more effective communication with final users, with an increased attention to real-world deployment.

Keywords: Human-Home Interaction, Smart Homes, Domotics, Intelligent Homes, User Needs, User-In-the-Loop

1. Introduction

Ambient Intelligence and Pervasive Computing research is currently shaping a vision of an home of tomorrow [11] that will be highly autonomous and so clever to support and anticipate users in their everyday tasks and needs. According to Cook et al. [7], Ambient Intelligence systems are new digital environments that pro-actively, but sensibly, support people in their daily lives. The degree to which this support is evolving and whether users are, or will be, ready to accept it still remains to be investigated.

Even if final users are increasingly playing a relevant role in this research field, they still appear quite far from cutting-edge developments of AmI research. Such a distance is clearly perceived by observing the worrying lack of user-validation and real-world trials of many published AmI frameworks and solutions. Although many examples can be found where envisioned interactions and functionality are verified against users' needs and wills, most of "intelligent" policies and algorithms proposed in the literature are designed and validated without involving the human inhabitant, often resorting to laboratory simulation [6,22]. This issue is highlighted both by the absence of public databases reporting common user preferences and user behaviors, and by the current lack of actually inhabited Smart Homes.[1] The research community is gradually becoming aware of this lack of user involvement: for instance the IST Advisory group has stated a goal that AmI must facilitate human contact [12]; fur-

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[1] Most of them are in University Campuses, e.g., the Gator Tech Smart House [13]

thermore Cook et al. [7] in their recent AmI survey paper explicitly state: "*current AmI research has actually raised fears of isolationism [4]. A new direction that can be forged for AmI researchers is to investigate mechanisms for supporting and enriching human socialization and interaction, and orient AmI toward community and cultural enhancement.*"

Understanding if this gap between advanced AmI research and general public expectations actually exists, what are the causes (e.g., the current scarcity of inhabited smart homes can be both a cause and an effect) and measuring the gap amplitude is clearly a difficult and challenging task. Nevertheless, to foster a seamless and integrated evolution of residential buildings into next generation intelligent homes, users must definitely become part of the whole process, driving, with their needs, the next evolution of AmI research.

According to these emerging requirements, this paper applies the user centered approach to AmI by reporting the results of a really simple, yet interesting, poll that the authors subministered to their university staff, and to the partners of an European network of excellence[2].

The poll has been explicitly conceived as a free think tank with the main aim of understanding the feeling of normal people with respect to future home environments. It is composed of only one really broad, and free question: "What would you ask to your home if it were intelligent?".

Results are interesting: although being subministered to unfiltered groups, with different sizes and cultural backgrounds, the main reported needs converge on the same macro-areas of *comfort* and *household tasks*. Moreover, most of required features, often ironically or faithlessly expressed in the survey, can be actually addressed with nowadays commercial technologies, either directly or by designing suitable integrations. In the great majority of answers, users show a strong attention to real, tangible needs, while most charming research topics such as information mobility, integration and sharing only play a marginal role, being "masked" by more prosaic tasks such as floor vacuuming or food preparation and provisioning.

The remainder of the paper is organized as follows: Section 2 reports relevant related works and findings. Section 3 describes the poll deployment by reporting poll goals, subministration modalities and involved information. Section 4 provides details on the demographics of involved persons and about the composition of the two interviewed groups. Poll responses categorization and harmonization is described in Section 5, while Section 6 reports most interesting needs emerging from the poll, thus building the basis for further considerations and research. Eventually Section 7 discusses the poll findings and Section 8 concludes the paper and proposes future works.

[2]The COGAIN (COmmunication By GAze INteraction) network

2. Related Works and Previous Findings

Understanding what users are expecting from future homes is an increasing driver of human-home interaction research. In parallel to the growing technological effort on Ambient Intelligence, user needs are slowly emerging [8], and consequently they are becoming focus of an increasing number of user studies. Early studies conducted by Berg in 1994 [3] show that a sensible gap between AmI research and real user expectations is present since the first, seminal AmI works. In her study, Berg interviewed designers of a number of experimental smart homes, asking how they thought technology might help and she found that designers "*manifest*[ed] *neither interest in nor knowledge of house work. The home is acknowledged as an important area of everyday life, yet the work that sustains it is rendered invisible*." Although early in the AmI landscape, this study is still relevant and is being confirmed by results coming out of our "Intelligent Home Survey".

A broad study on exploring and enhancing the home experience [9] was conducted by Eggen et al. in 2003. They employed extensive user studies for understanding what "home" actually means to people, and to find out how people would like to live in their "dream home." From their user analysis a clear view of the home emerges, which is slightly misaligned with respect to current AmI research, while findings from the poll presented in this paper are coherent with this early analysis. According to Eggen's study, people's view of the home can be summarized as follows:

- *home is a feeling*, i.e. it is a cozy, trusted and safe place, a place to return to;
- *feeling good is part of the home experience*, such a feeling is sustained by pleasant atmosphere and decorations, customized on home inhabitants preferences;
- *doing what you want*, any home inhabitant must be free to perform its own activities, without being guided or forced by AmI in the home;

– *you own stuff*, and not vice-versa. This emphasizes the need of feeling in control, thus contrasting the quest for autonomous behavior typical of many AmI research efforts.

When confronted with the possibility of shaping their own future homes, users participating in Eggen's study showed mixed feelings about smart homes. However three clear trends emerged:

(a) People want to be in control, always. They want control over when and how things are done and to what degree the home takes over; this finding is confirmed in our study.
(b) People are interested in the benefits of technology. When interviewed about the role of technology in the home, they almost never talk about the technology itself. Instead they do talk about the technology in reference to their current use of technology and about possible improvements. E.g., they do not talk about wireless appliances, instead they ask for more controlled electric sockets. This finding also emerges from our study, showing a much higher interest in comfort and home management tasks than in "advanced," mobile and futuristic interaction patterns.
(c) The future home is as it is now, but better. In the future, the feeling of the home shall remain the same, the core values of the home must be left untouched.

More recent results are focused on single aspects of human home (or building) interaction. Röcker, for example, conducted a study on the perceived usefulness of Ambient Intelligence applications in office environments [19], with the goal of understanding whether the core functionality provided by AmI applications are accepted by potential users, and therefore are likely to be used in future offices. Two hundred questionnaires have been distributed to office employees in Germany and USA, pertaining 8 main scenarios: adaptation of concepts, personal well-being, personal encounters, speech input, ambient displays, personal reminder, asynchronous communication, public activity histories. Results show that the usefulness and ease-of-use ratings of most scenarios range between 60% and 70% of the maximal possible scores. Interestingly in this study, as in ours, the scores given to technologies often purported to revolutionize the nature of (office) environments are not remarkably high. Nevertheless, a considerable potential to increase the usefulness and ease of use of AmI solutions can still be identified.

Misker et al. [15] investigated user preferred interactions for activating AmI scenarios in their homes. Compared with the broader investigation tackled in this paper, Misker's research is focused on a single aspect of AmI in real homes, however results are interesting as they point out a strong user preference to one-button activation of AmI complex scenarios. In a sense this confirms the perception rising out the investigation described in this paper: interaction features often described as highly innovative and disruptive get lower attention from home inhabitants that, in turn, are more focused on simple and effective home control.

3. What Would You Ask to Your Intelligent Home?

Understanding what users expect from Intelligent Homes is the main motivation underlying the poll design and the provocative choice of abandoning the classical survey form in favor of a more open, though less formal, web-based think tank form.

By actively working with real users, e.g., ALS affected patients in the context of the COGAIN network, and on real installations, e.g., the Maison Equipée in Aosta, we perceived a worrying mismatch between the general trends of the AmI research we, and more in general the research community, are pursuing, and the real user expectations in terms of home functionality and features.

On one hand, in our daily work, we had a perception that the fanciest features required by users were actually "easy" to design and implement by applying state-of-the-art AmI and Domotics. On the other hand, we detected a slight drift of our research towards "pushing" new needs on users instead of trying to address the existing ones [16]. We therefore were urged to investigate more on actual user expectations, with the long-term goal of contributing to provide cost-effective, ready to deploy AmI solutions addressing these emerging needs.

3.1. Design

We considered several possible forms of user survey [21] for gathering users' expectations about intelligent environments, from direct face to face interviews to web-based questionnaires. Among these possibilities, we decided to take a very light approach allowing participating users to express their needs freely, even by playing jokes with our question(s).

We decided to focus on real, unconstrained user feelings, expressed as answers, or wishes, arising from a single open question:

"What would you ask to your home if it were intelligent?"

With the same open approach we decided to only gather minimal demographics information about the poll participants, enabling them to feel "safe" through explicit anonymity and by avoiding collection of personal preferences and information.

To support this "transparent design" goal, we deployed the poll in two different parts: demographics collection and free answer to the question.

In the demographics stage we only asked not sensitive user information such as:

- the continent in which the user was born;
- the current employment (unconstrained field);
- the age, with a 10 years granularity (e.g., 16-25, 26-35,...);
- the user gender, to detect possible differences between male and female preferences.

In the question-answering part, participants were enabled to provide 1 to 5 answers to the open question in their mother tongue or in English. The total poll-filling time was estimated around 3 minutes, thus enabling users to quickly complete the task and to mitigate the not-complete answer problem typical of longer surveys.

3.2. Subministration modalities

We subministered the survey to an audience (called the PoliTo user group) with a relatively high education level: people working in our university, such as technical and administrative staff, faculty and Ph.D. students.

The poll was subministered in form of a web-based questionnaire and results were gathered by means of the well known Lime Survey[3] tool. Recruitment did not include any payment or incentive and relied on a one-shot e-mail request sent to the whole e-mail domain of our university. Avoiding to apply follow-up techniques for the survey ensures responses from highly collaborative participants, only. These spontaneous participants are more motivated to freely express their opinions and needs on the intelligent environment topic, without cultural or behavioral constraints [1,2,14,23].

We allowed submissions to the poll for a 3 month time span, after which we closed the on-line poll and started the subsequent data filtering and elaboration.

[3] http://www.limesurvey.org/

The same poll was independently sub-ministered to the partners of the COGAIN European Network of Excellence. This second user base has almost the same education level of the "PoliTo" set, but a completely different cultural background. Most of the COGAIN partners, in fact, live in northern Europe and almost all have strong experiences on very specific research fields: computer-vision and therapeutics for communication by gaze interaction. We expected the two communities to have really different perceptions of home intelligence and, consequently, very different needs that intelligent homes are expected to fulfill.

Common needs arising from this so-diverse groups of persons are likely to be shared among a great part of possible AmI users, at least those with higher education. Even if not statistically significant, poll commonalities have the potential to guide the design and development of more fine-grained and statistically sound surveys, acting as pre-test investigations. In the long-term, a major involvement of users in guiding AmI research priorities must be fostered, leading to an increased user co-design in AmI.

3.3. Results overview

According to our expectations, the poll response rate was relatively low (14.15%) for the PoliTo user group while for COGAIN it cannot be estimated, due to the unknown size of the group.

A total amount of 246 PoliTo employees and 16 COGAIN members participated to the poll expressing 671 and 78 answers, respectively. Since every user was allowed a maximum number of 5 answers, the mean response rate per user is of approximately 2.7 answers for PoliTo users and of 4.9 for COGAIN users. Poll answers are quite diverse in terms of both language style and phrase structure. They include:

a) imperative commands,

> *Check the weather forecast and adjust internal temperature accordingly.*

b) kind and informative requests,

> *Do the radiation, humidity and the light have the optimal values? If not, what should I do?*
>
> *The street noise are too loud. How can we diminish them?*

c) expressions of requirements,

Automatic indoor air quality guaranteed by windows openings or mechanical ventilation (despite this already exists)

d) and jokes.

Switch off my neighbor's TV, please

Sopprimi la mia coinquilina
(kill my roommate.)

Most poll answers were in English (439 for PoliTo and 78 for COGAIN), although often misspelled and/or with grammar errors, while a significant response subset was written in other native languages, such as Italian (126) and Spanish (7).

Users were free to assume a voice based interface, as the poll question, by itself, leaves open (and actually fosters) the possibility of speech interaction with the home. In the "*What would you **ask** to your home if it were intelligent?*" phrase the verb "ask" has, in fact, a clear affordance to speech-based operations.

The whole set of survey answers, properly made anonymous and aggregated in categories (see Section 5) is freely accessible at the authors website[4].

4. User Demographics

The poll answers of both user bases have been analyzed for extracting more detailed information about the composition of participants, in terms of age, gender and employment. Following subsections provide finer detail on each of the two user groups.

4.1. PoliTo

According to the employment statistics of Politecnico di Torino (PoliTo), the total amount of employees is 1738, of which 1051 males (60%) and 687 females (40%). Poll respondents were 246 (14.15%), of which 161 males (65%) and 85 females (35%). Low response rate was expected, due to the absence of follow-up techniques, and to the resilience of employees to poll answering. Users responding to the poll at the first invitation, however, tend to be more spontaneous, and to express their needs and feelings more freely. Interestingly, the distribution of males and females among answerers reflects quite well the actual employees distribution. However, it differs from the country-wide relative distribution of males and females, therefore gender related data in the following sections can only provide a qualitative impression of the differences between male and female approaches to next-generation homes.

Most poll answers were provided by young people, both globally (see Table 1) and inside each employment category.

Table 1
Age distribution for the PoliTo answerers

Age	Percentage
16-25	9%
26-35	52%
36-45	23%
46-55	10%
56-65	4%
66-75	2%

To analyze the composition of the responding users, we normalized the freely expressed employment of answerers into 16 main work positions, covering a superset of the official position categories in the PoliTo institution. Positions do not derive from a formal categorization process but they emerge as common job definitions given by survey users while answering the demographics section, therefore partial overlap may occur. Table 2 shows the distribution of interviewees with respect to the employment categories.

Table 2
Employment distribution for the PoliTo user group.

Employment	Percentage
Administrative staff	12%
Technical staff	11%
Student	6%
Ph.D Student	13%
Research assistant	6%
Researcher	19%
Professor	12%
Architect	4%
Biologist	0%
Engineer	6%
Lawyer	1%
Academic	1%
Sociologist	0%
Consultancy	0%
Occupational therapist	0%
No-answer	9%

[4] http://elite.polito.it

It can be easily noticed that the "not answered" figure is sufficiently low, meaning that the privacy statement in the poll, and the poll structure itself has been efficient in conveying the "anonymity" and safeness of poll taking. The overall distribution of answerers with respect to their employment is not particularly significant by itself, but becomes interesting when analyzed in comparison with the employment distribution in Politecnico di Torino. In this case, in fact, differences between general employment and respondent's job category distributions can be spotted. To enable such comparison the gathered data has been reconciled with the PoliTo official employment categories, leading to the figures reported in Table 3.

Table 3
Comparison between overall PoliTo employees and poll answerers employment.

Employment	PoliTo (All)		PoliTo (Poll)
Administrative staff	15%	$\approx$	16%
Technical staff	11%	$<$	15%
Ph.D Student	23%	$>$	19%
Research assistant	24%	$>$	16%
Researcher	11%	$<<$	26%
Professor	16%	$>>$	8%

Table 3 shows some interesting differences between the whole set of PoliTo employees and the poll answerers. While the *administrative staff* answer rate is almost coherent with the proportions of this category with respect to the whole employees, all the other employment groups show appreciable differences. It is evident that people in lower-grade research positions (*researchers, research assistants and Ph.Ds*) are more kind to participate to the poll probably due to their appreciation of the poll value for scientific purposes. *Professors*, on the other hand, show a reduced response rate which might reflect the shift of responsibilities away from foundational research, usually carried by younger people. Eventually, the slight increase in the *technical staff* response rate can be ascribed to a specific interest in advanced technical solutions.

4.2. COGAIN

The COGAIN user group is much smaller than the PoliTo set and its main purpose in the paper is to cross-check the harvested user needs. It is composed of researchers, professors and practitioners participating in the COmmunication by GAze INteraction European network of excellence. The total number of poll participants is 16 of which 11 male (69%) and 5 female (31%). Due to the reduced set size, nothing can be derived from the gender distribution between participants.

Employment of COGAIN participants has been classified according to the same 16 categories defined for the PoliTo user group. Table 4 reports the corresponding figures. It can easily be spotted that the employment distribution mainly involves those skills typical of the specific research field in which COGAIN is involved.

Table 4
Employment distribution for the COGAIN user group.

Employment	Percentage
Administrative staff	0%
Technical staff	18.75%
Student	0%
Ph.D Student	6.25%
Research assistant	0%
Researcher	18.75%
Professor	12.5%
Architect	0%
Biologist	0%
Engineer	12.5%
Lawyer	0%
Academic	0%
Sociologist	0%
Consultancy	18.75%
Occupational therapist	12.5%
No-answer	0%

5. Faceted Classification of Survey Results

To capture most information content out of the free form answers (see some representative samples in Section 3, and in Tables 11 and 14), we categorized poll responses into orthogonal categories, or *facets*. Facet classification [17,18,24] is particularly well suited since it is expressly designed for representing information objects (i.e., answers in our case) according to different perspectives (facets). Every information object can belong to more than one facet at the same time and hierarchical composition of facets is allowed. Widely applied to searches over domain-

specific information sets [10,20,25], facet classification and browsing can be successfully exploited as a content-rich analysis and exploitation tool for poll results. After classifying poll answers in suitable facets, interactive interfaces (e.g., the MIT Exhibit[5]) can, in fact, be leveraged for filtering answers on the basis of facet values and therefore for deriving simple statistics and conclusions on the poll result set, according to different, possibly combined, perspectives.

5.1. Facets

We define 12 different facets under which poll responses are categorized. These 12 categories are mainly divided in two complementary sets related to demographic information and to actual poll answers, respectively. The demographic set includes 3 facets directly corresponding to the user information gathered through the poll: *age*, *gender*, and users employment (*work*). The answers set, instead, encompasses 9 facets, described in Table 5. Each facet can assume a set of predefined values, possibly organized into hierarchies (e.g., the Target facet). Following subsections detail the most relevant facets describing their content and allowed values.

5.1.1. Feasibility

The *feasibility* facet classifies user needs and requirements with respect to the time frame in which such issues will be addressable. The possible values for this facet are:

a) *Present* requests can be addressed with currently available commercial technologies, or with suitable integrations thereof;
b) *5 years* needs are currently being addressed and solved in the research community, therefore the expected time frame for their practical adoption is short, possibly no more than 5 years;
c) *15 years* requirements and/or features will be probably addressed in a relatively near future but a clear estimation of when these issues will be addressed (if they will) cannot be derived;
d) *Jokes* include things that are typically unfeasible either technically or on the basis of ethical considerations. For example, one answerer has expressed the wish of having an intelligent home able to kill her annoying room mate, this is clearly non-ethical, although in principle it might be feasible.

[5] http://simile.mit.edu/wiki/Exhibit

Table 5
Categorization Facets for user responses.

Facet	Description
Feasibility	of required feature/functionality
Activation time	identifying when the request must be fulfilled
Scope	the application field the request is concerned with
Technologies	required to address the expressed need
Sentence type	the kind of sentence used to express the need
Sentence complexity	the phrase complexity in terms of structure and adopted words
Sentence language	the language in which the poll answer is expressed
Target	the objective of the required functionality, i.e., the kind of need to be supported
Task	the type of task, either informative or action-based, required to fulfill the user requests

5.1.2. Activation time

Responses to the poll questions have been classified according to the time instant in which they must be executed (see Figure 1). This time instant can either be immediate (direct requests or commands), or can happen in the future depending on some conditions. In the latter case, conditions can be based on some specific device or environment state, e.g., "*lock the doors when I'm going out*", on some recurring event such as gas losses monitoring or on time-based activations, e.g., "*heat the oven by 7:00 PM*".

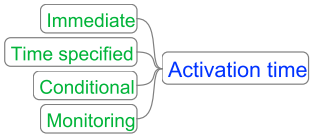


Figure 1. The *activation time* facet.

5.1.3. Scope

Every poll answer refers to specific objects in the home environment, i.e., it has a well defined scope of application (shown in Figure 2) that we cluster in 3 different categories: device, group and scenario. The device scope is associated to answers that refer to a specific device, e.g., "*heat the oven at 7:00 p.m.*". We speak of group activation when the poll answers involve the simultaneous activation of multiple devices, mentioned in the user statement, e.g.,

"*open the door and shutdown the heating system*". Finally, scenario activations involve the coordinated operation of multiple devices that together accomplish a (pre-)defined task such as preparing the living room for movie watching: this implies dimming the lights, switching on the Home Theater and the TV set and possibly switching on the answering machine.

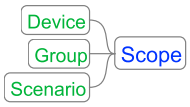


Figure 2. The *scope* facet.

5.1.4. Technologies

The technology facet identifies the tools and solutions required to support users' requests (Figure 3). Each poll answer is classified against the technologies facet, by selecting all applicable technologies involved in tackling the answer-related issues. The set of possible technologies is defined bottom-up, as it arises from the analysis of individual poll answers, and it is incrementally updated and uniformed during the whole poll response analysis.

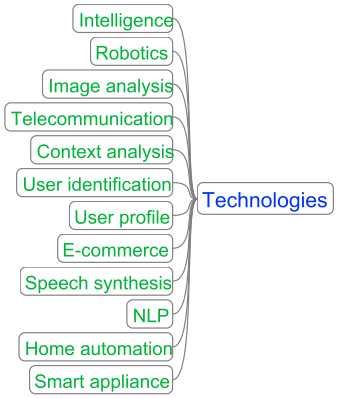


Figure 3. The *technologies* facet.

5.1.5. Sentence type, complexity and language

The sentence type, complexity and language facets provide a basic categorization of the verbalization and written formalization of user needs, distinguishing between language expressions reporting direct users *request*s

> *Are you able to check fire or smoke troubles?*

and general statements about home-related *requirement*s,

> *Automatic control of all the safety of the home*

between *simple*

> *Are you OK? (Do you need any sort of maintenance?)*

and *complex* phrasal constructions,

> *Ask me if I want to activate some systems when recommended (e.g., shading in sunny days, water plants when dry, etc.)*

and identifying the language in which the poll answer was written: English, Italian or Spanish.

5.1.6. Target

The target facet identifies the central point of the poll, i.e., users needs. To structure this facet, we adopted a bottom-up approach where emerging information is first gathered, and then categorized into hierarchical clusters of target activities, sharing peculiar features such as the application (energy vs. housekeeping), the functional area (diagnostic vs. interface) and/or the underlying needs (energy concerns vs. comfort and entertainment). Associations between poll answers and target values is carried by a single human reviewer to avoid classification incoherence.

Each facet entry is further refined by means of subtopics, resulting in a 3 level deep hierarchy of values that can be associated to every poll answer. Multiple associations are allowed, for example one user statement can at the same time involve food management and shopping. Main target sub-topics include:

- **Appliance Interface** representing requests and requirements that involve interfaces for specific appliances, e.g., speech operated dishwashers;
- **Clock**, enclosing requirements about timing and scheduling activities;
- **Weather**, grouping activities that depend on the external weather conditions, e.g., washing clothes might not be useful if outside it is raining;
- **Safety**, refers to all the user requests or requirements about their own safety or about the safety and security of the house itself;
- **Energy saving**, involves all the concerns about energy consumption and its reduction;
- **Communication**, encompasses all the user communication needs such a reading e-mails, talking with distant familiars, etc.;
- **Diagnostics**, pertains the ability of the house, or of some of its subsystems, to detect and (if possible) repair malfunctions and failures;

– **Household tasks**, groups all tasks usually carried for keeping the home clean and comfortable;
– **Comfort** represents comfort specific issues such as light regulation, environment heating/cooling, shutter and windows operations;
– **Personal assistance**, represents all the poll answers (requests) where users are asking the home to help them doing tasks or to help them remembering things.

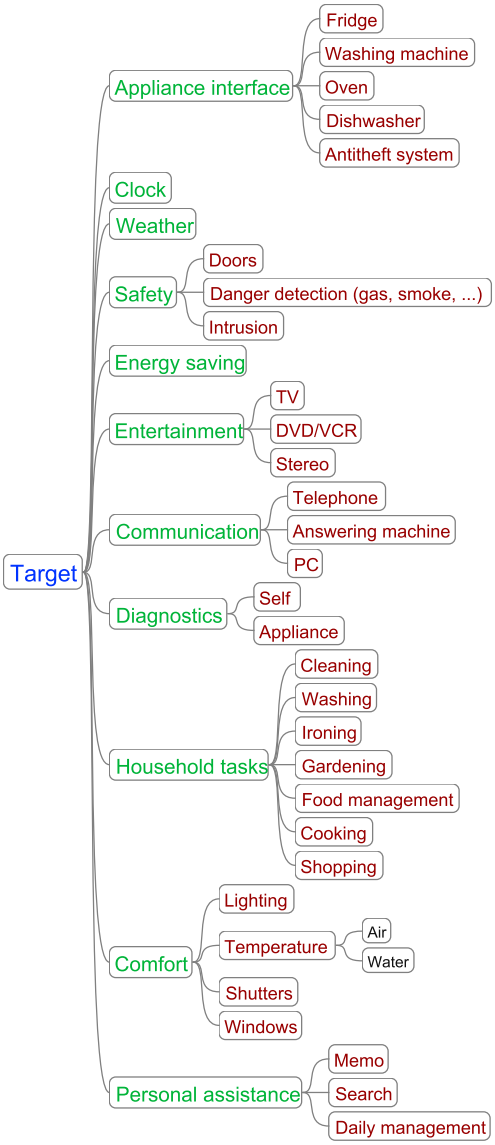


Figure 4. The *target* facet.

A typical example of phrase classification is the following: given the poll response "*Automatically replenish stocks of food in the fridge*", this requirement is manually categorized as pertaining to targets: Fridge, Food management, Shopping.

5.1.7. Task

The task facet is really simple and only discriminates between poll answers requiring the home to carry actions and requests for information, either about the house state or involving the user, e.g., the last received e-mails.

5.2. Exhibits

Poll answers, categorized according the 13 facets described in previous sections, have been made available for further analysis in form of *exhibits*. An exhibit is a web-based representation of some faceted base of knowledge, that exploits the MIT Exhibit framework. Exhibit allows navigating and filtering poll answers by iteratively selecting restrictions of permitted facet values. For example, if a poll analyzer wants to understand what kind of comfort-related needs users express if they are 27 years old and they hold a Ph.D, it is sufficient to filter through Exhibit the poll results, as shown in Figure 5.

To support efficient retrieval of poll data and better organization of represented aspects, the 13 categorization facets have been visually organized into 5 areas described in Table 6.

Table 6
Main areas of the survey exhibit.

Area	Description
Sentence	It groups facets describing the grammatical and phrasal complexity of the given poll answer
Interaction	It involves the task, activation time and scope facets, identifying the expected human-home interaction modalities
Users	It provides means to filter results on the basis of demographic data such as the user age, the current job, the gender, etc.
Objectives	It encompasses only one facet, the target, highlighting the goal of interactions and functionality required by the interviewees through the poll
Technology	It includes both the feasibility evaluation facet and the required technology facet, thus highlighting the technological requirements that must be fulfilled for satisfying specific classes of needs identified by filtering on the other facets

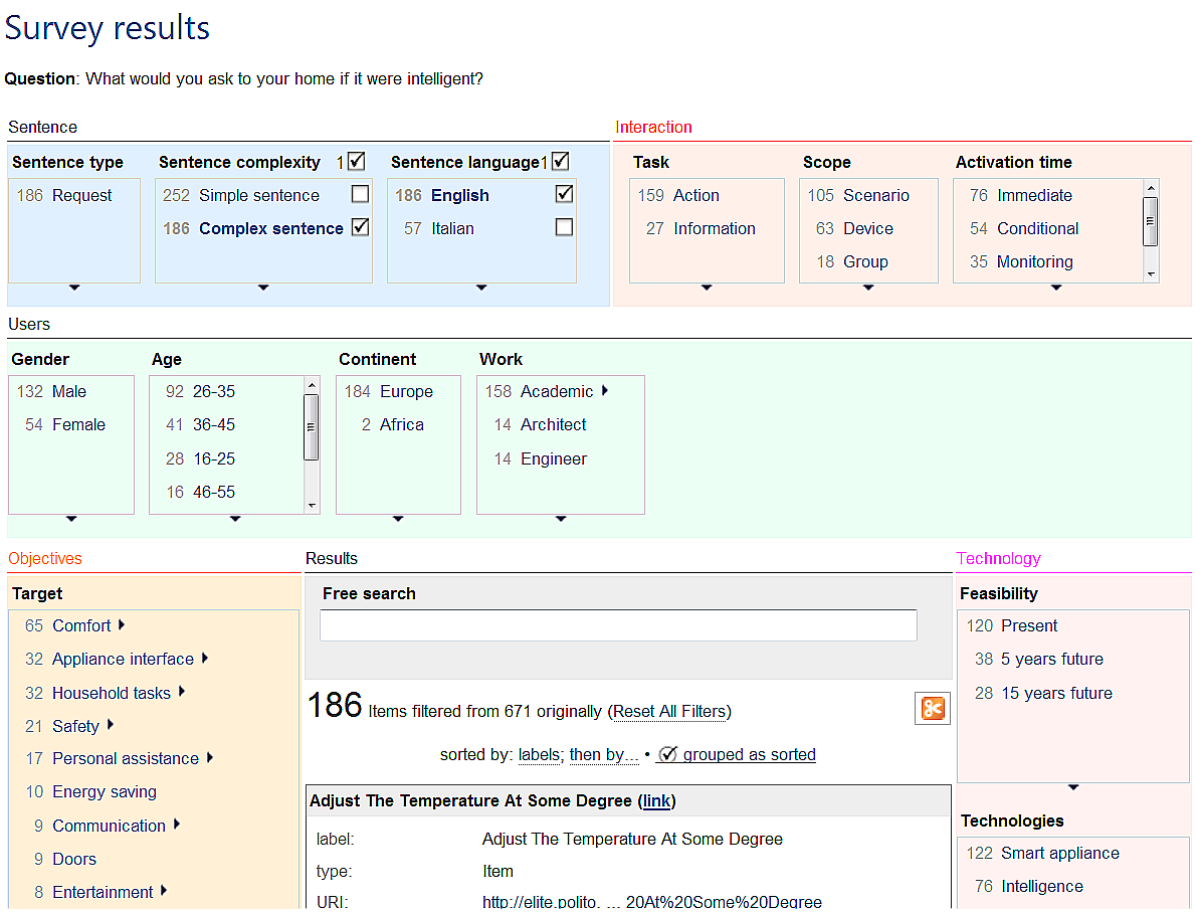


Figure 5. The poll result exhibit for the PoliTo set.

6. A Taste of User Expectations

We deployed the poll results analysis in two main phases: analysis of general trends and focus on emerging "hot topics."

6.1. General Trends

In the first stage, poll results have been analyzed and outcomes from the PoliTo and the COGAIN user groups have been compared. To identify the main user needs and how they are (or will be) addressed by either commercial or research solutions, we need to concentrate mainly on the target and the feasibility facets. Starting from the feasibility of required functionality we derive general statistics for both user groups (see Table 7).

An outstanding result is that most of currently not addressed user needs can actually be handled by either applying commercial solutions or by providing suitable integrations of more than one technology, e.g., by bridging domotic systems and smart appliances such as robot vacuum cleaners, etc. In both user groups, most of requirements (64% for PoliTo and 74% for COGAIN) can be tackled nowadays, but users are not aware of this possibility, and they perceive these solutions as distant and futuristic. By bringing to the user the currently available research technologies we can overcome this gap, and we can cover more than 80% of user expectations about Intelligent Environments. Fur-

Table 7
Feasibility of user needs emerging from the poll, for both user groups.

Feasibility	PoliTo	COGAIN
Present	64%	74%
5 years future	21%	15%
15 years future	12%	10%
Joke	3%	1%

thermore, we can exploit *15 years future* requirements and some *jokes* as inspiring guidelines for next AmI developments, thus enabling a better involvement of final users in shaping homes of tomorrow.

Besides feasibility, we are also interested in understanding the main interest areas for users, e.g., comfort vs. safety. Therefore, poll answers, categorized along the target facet, have been analyzed for finding preferred application areas. Table 8 reports the corresponding results.

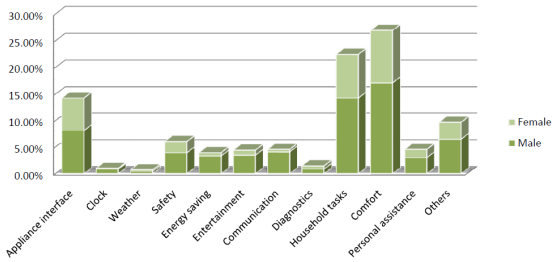
Table 8
Preferred application areas for both user groups.

Target	PoliTo	COGAIN
Appliance interface	15.75%	2.15%
Clock	1.17%	0.00%
Weather	0.84%	1.08%
Safety	6.70%	5.38%
Energy saving	4.36%	9.68%
Entertainment	4.86%	11.83%
Communication	5.03%	2.15%
Diagnostics	1.68%	1.08%
Household tasks	24.79%	20.43%
Comfort	29.82%	31.18%
Personal assistance	5.03%	15.05%

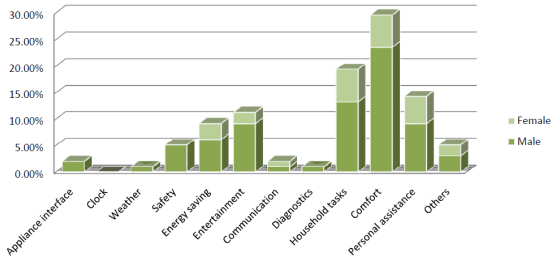
Interestingly, even if the two user groups are quite different in terms of cultural background and of cardinality, they share the highest rated areas of interest for intelligent home applications. In both cases, comfort issues play the most relevant role, nearly followed by household tasks. Such a finding can be interpreted as a major drive of users towards practical issues of everyday life such as food preparation, food provisioning, house cleaning, relax and social activities. On the other hand, more advanced functionalities, which are more appealing to researchers, such as energy saving, diagnostics, communication and so on, deserve lower attention, probably being masked by more pressing mundane needs.

Figures in Table 8 show two additional "relevant topics": Appliance interface for PoliTo and Personal assistance for COGAIN. The sentences involving Appliance interface are a subset of comfort responses, where specific appliances have been mentioned (e.g., oven, fridge, etc); COGAIN sentences are generally simpler, and seldom so specific to mention appliances. On the other hand, the higher Personal assistance figure in the COGAIN group is justified by the higher interest to the person's needs by health care operators, more frequent in that group.

Target activities might depend on users' gender. To account this possibility, we analyzed the target facet distribution, among the allowed facet values, highlighting differences between males and females (see Figure 6).



(a) Detailed target areas of PoliTo poll answers, by gender



(b) Detailed target areas of COGAIN poll answers, by gender

Figure 6. Detailed application areas for both user groups, classified by gender.

By comparing the PoliTo set with the COGAIN user group, some differences emerge between the relative importance attributed by both genders to comfort and household issues. These discrepancies raise a set of questions about perception of relevant home tasks, which might be different between northern and southern Europe. Findings from this first poll can hence fuel new, more targeted investigations and can drive the selection of representative user samples.

6.2. *Hot Topics*

Given the general trend of the survey outcomes, we decided to focus on poll responses related to *comfort* and *household* tasks. We therefore devised further analysis of user needs (requests) in both fields, taking into account different perspectives associated to male and female answerers.

6.2.1. Comfort

We compared the relative importance of comfort "sub-topics" with respect to the total amount of responses in this domain. Comparisons involve both user groups. As shown in Table 9, temperature and light regulation are the highest rated areas (around 30% in both sets, with slight variations) whereas automatic operation of windows, shutters and other devices deserve comparably low attention (around 15%).

Table 9
Distribution of comfort needs for both user groups.

Comfort Type	PoliTo	COGAIN
Lighting	35.76%	35.14%
Temperature	35.76%	32.43%
Shutters	8.48%	16.22%
Windows	20.00%	16.22%

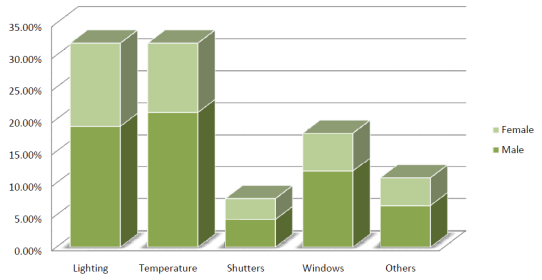
Looking at the answer distribution with respect to interviewees gender (Figure 7) we can observe that females appear to dedicate slightly more attention to lighting-related needs, with respect to temperature settings, whereas males have no clear preference between the 2 concerns.

All the other topics such as windows and shutter actuation, etc., deserve almost the same attention from both genders. It is interesting to notice that distributions among target sub-types for both the PoliTo and the COGAIN user groups show almost the same trends, thus providing a hint on the general applicability of derived qualitative figures.

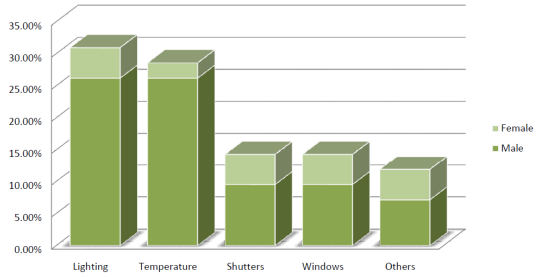
Comfort issues analysis includes an estimation of the feasibility of related requests, as they emerge from the poll. Such a detailed view allows to better understand to which extent user needs can be satisfied by current, or near to come, technologies. By looking at Table 10 we can easily notice that nearly all expressed needs are actually addressable by applying current technologies or suitable integrations of existing systems. Table 11 reports some examples chosen from the feasible poll answers subset related to temperature and lighting comfort and it shows solutions that can nowadays be applied.

6.2.2. Household tasks

Household tasks requirements, i.e., user answers that can be categorized as related to the housekeeping domain, constitute the second most important area of interest emerging from overall results. Similarly to comfort, we analyzed the distribution of household related tasks with respect to the allowed facet values, for both user groups (see Table 12).



(a) Distribution of comfort needs for the PoliTo user group, classified by gender.



(b) Distribution of comfort needs for the COGAIN user group, classified by gender.

Figure 7. Distribution of comfort needs for both user groups, classified by gender.

Table 10
Comfort requirements feasibility for both user groups.

Feasibility	PoliTo	COGAIN
Present	91%	87.1%
5 years future	8%	6.45%
15 years future	1%	6.45%

The figures in Table 12 show a clear prominence of requirements lying in the house cleaning domain, especially for PoliTo users. In this user set, 45% requests are involving house keeping/cleaning, while the second concern in terms of requirements can be identified in food management (15%). On the other side, this clear bias towards cleaning is not observable in the COGAIN set where no difference can be appreciated between the percentage amount of house cleaning (24%) and cooking (24%) requests.

When the distribution of household tasks is analyzed with respect to the gender of poll answerers (Figure 8) additional interesting clues can be derived. In the COGAIN group both males and females are sensibly con-

Table 11
Examples of nowadays solutions fulfilling user requirements emerging from the poll.

Requirement (poll answer)	Possible solutions
Lighten the kitchen lights at a given hour	Simple Home Automation, e.g., X10, KNX, MyHome, or Smart Home solutions
Switch on the air conditioning	Remote Control, Simple Home Automation or Smart Home solutions
Switch on the heating system one hour before I'm back home	Integration between office access control (and/or user agenda) and remote home management (e.g., through OpenRemote)
Adjust the temperature at some value in degrees	Automated heating control
Automatically turn off the lights after a certain time if no one is in the room	Simple presence detection (e.g., through IR detectors) and home automation
Check if I left the garage lights on	Simple Home Automation or Smart Home solutions

Table 12
Distribution of household needs for both user groups.

Household need	PoliTo	COGAIN
Cleaning	44.85%	23.81%
Washing	3.68%	9.52%
Ironing	7.35%	4.76%
Gardening	7.35%	0.00%
Food management	14.71%	19.05%
Cooking	11.76%	23.81%
Shopping	10.29%	19.05%

Table 13
Household requirements feasibility for both user groups.

Feasibility	PoliTo	COGAIN
Present	24%	59%
5 years future	44%	30%
15 years future	32%	11%

cerned with cooking, particularly females for which cooking is the most relevant task (in percentage), while in the PoliTo set, cooking is relatively neglected.

On the converse, home cleaning assumes much more importance for PoliTo users and for male COGAIN users while females of the latter group are not too much concerned about cleaning the home.

According to the main goal of identifying possible gaps between current AmI research and user needs about intelligent homes, we detailed the feasibility distribution of the household facet by applying the same approach used for the comfort domain. Table 13 reports the corresponding outcomes.

As emerges from the feasibility table, household related requests are not as favorable as comfort tasks: feasible requests fall down to only 24% for PoliTo users while for COGAIN people they still get the highest share of preferences (59%). On the other hand, solutions affordable in 5 years or less cover the relative majority of PoliTo requests and get the second relevance score for COGAIN. Eventually, deep future features (15 years future) assume a quite relevant role in this facet, meaning that much research work has still to be carried, or, in other words, that the household task domain has quite been neglected by streamline AmI research.

In order to better understand the type of requests typically involved the household task domain, and what technologies are involved, we report a sample of poll answers in Table 14.

7. Discussion

Gathering user expectations about the homes of tomorrow is actually a really complex task and many factors shall be considered in this evaluation such as literacy, age, country, cultural background, health conditions, etc. Results of related surveys (and of the one illustrated in this paper) may be greatly influenced by the above factors and generalization might prove to be a daunting task, even in a single country, e.g., Italy.

While already providing a first glimpse on user expectations about next generation homes, the adopted approach has clearly some shortcomings that may partially be addressed in future investigations on the same topic. Aiming at statistically significant and generaliz-

Table 14
Examples of current, 5 and 15 years future solutions that may tackle household-related user requirements emerging from the poll.

Requirement (poll answer)	Possible solutions	Feasibility
Auto-Clean home when I'm out: above all vacuum cleaner	Home Automation, e.g., KNX or MyHome, or Smart Home technologies (for scheduling and presence detection) integrated with cleaning robots (e.g. the Roomba[a] vacuum cleaner)	present
Clean yourself, please	Home Automation, e.g., KNX or MyHome, or Smart Home technologies (for scheduling and presence detection) integrated with cleaning robots (e.g. the Roomba[a] vacuum cleaner)	present / 5 years future
Give me an alert when food in the cupboard is near its "Expiration Date"	Object tracking (e.g., through barcode or RFID)	present / 5 years future
Tell me what do I have to buy at the supermarket	Intelligence, User profile, Smart appliance & home automation	5 years future
Please, iron the clothes	Smart appliance, Robotics	5 years future
Cook milk and coffee for breakfast 20min after the wake-up call	Smart appliance, Scheduling, Robotics?	present / 5 years future
Lava, stira e riponi gli indumenti incluso l'antitarme (wash, iron and order clothes in their correct places, without forgetting the moth repeller)	Smart appliances and Robotics	15 years future
Prepare my lunches and dinners according to my daily preferences, please	Smart appliance, User profile, Robotics, Intelligence	15 years future

[a] `http://store.irobot.com/home/index.jsp`

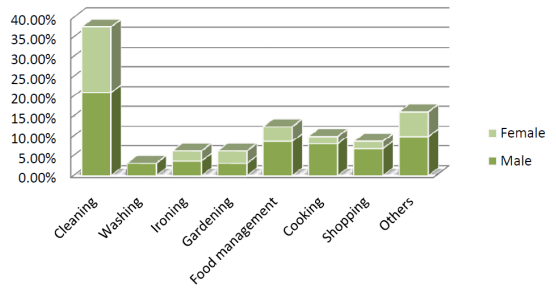
able results requires a more structured approach with a suitable selection of the user sample, of the test setting and of the required follow-up techniques. Even with such a careful design, and execution, results might fail to generalize over national boundaries due to different cultures, different home concepts, different approaches to technology, etc.

All these concerns have been considered when designing the intelligent home survey we presented and they lie at the basis of the adoption of a "light", think-tank approach to the survey. We are aware that the poll results cannot be generalized to all potential users, in all potential countries. In fact, the main goal of the survey is to start understanding why the adoption of AmI technologies is not taking off as expected by the research community.

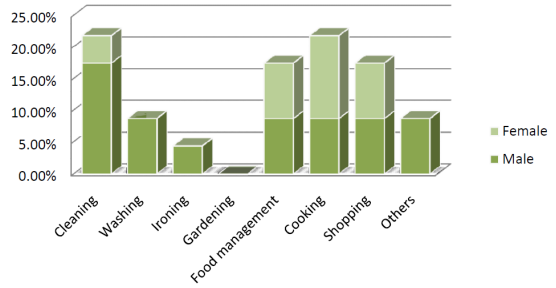
Survey results are almost exclusively focused on functional requirements while they nearly omit non-functional requirements such as privacy or security, which might a priori appear of interest to users. This evidence does not reflect our design choices, but clearly emerges from free answers given by the poll respondents, who never mentioned privacy and mainly referred to security as to intrusion avoidance. Motivations for this lack of data about non-functional requirements may derive from the survey formulation or may be due to users being unaware of privacy issues involving their smart homes. Actually, at least in Italy, the home is rarely identified with something that can be open to privacy breaches and home inhabitants are seldom aware of the privacy threats that might be related to home automation systems.

The "*What would you ask to your home if it were intelligent?*" poll has the value of highlighting a current lack of user need consideration in Smart and Automated Home design. The poll results can therefore fuel a possible new stream of integration research aimed at finding viable methodologies, and at designing suitable frameworks, for easing the implementation and customization of integrated home solutions based on existing technologies. We refer to this new research stream as to Human Home Interaction (HHI), sharing many goals and aspects with the well-known Human Computer Interaction research field, but focusing on the home. HHI is likely to be increasingly involved in the design of the homes and buildings of tomorrow.

The lack of user centered solutions highlighted by the poll does not necessarily mean that currently pur-



(a) Distribution of needs related to housekeeping for the PoliTo user group, classified by gender.



(b) Distribution of comfort needs for the COGAIN user group, classified by gender.

Figure 8. Distribution of comfort needs for both user groups, classified by gender.

sued Ambient Intelligence is not useful of that it will hardly be adopted. Instead, it shows the existence of a sort of "masking effect" where users are more concerned about the sensible lack of support to basic, but useful features, than with new facilities that have the potential to improve their everyday life quality. To rejoin AmI research and user needs, greater attention must be given to HHI design, involving more and more users in the design of their own future homes. In addition, research should better take into account and integrate with existing commercial solutions, and contribute to dissemination and information about their capabilities. Moving from the current approach based on "pushing needs" to a fairer approach of "supporting needs" [16] will likely boost the adoption of smart and automated homes, augmenting the diffusion of such flexible environments and possibly sustaining increased commercial adoption of these systems despite their higher costs of installation.

In this context we see a great potential for integration based approaches such as Dog [5] where the main concern is about using and exploiting potentialities of existing commercial systems instead of designing new solutions from scratch. Under the same view, emerging "lightweight automation" solutions based on ZigBee, ZWave and other wireless communication technologies can provide a great contribution to the creation of more affordable intelligent homes, easy to shape around specific user needs.

8. Conclusions

In this paper we reported the results of a really simple, but extremely insightful, poll on Intelligent Homes sub-ministered to our university staff, and to the partners of the COGAIN (COmmunication By GAze INteraction) European network of excellence. Results are quite encouraging: the main reported needs converge on the same macro-areas of *comfort* and *household tasks*. Moreover, most of required features expressed in the survey can be actually addressed with nowadays technologies, either directly or by designing suitable integrations.

In the great majority of answers, a strong attention to real, tangible needs emerges, while most charming research topics such as information mobility, integration and sharing only play a marginal role, being masked by more prosaic tasks such as floor vacuuming or food preparation and provision.

Poll evidence highlights the existence of a significant lack of AmI engineering, and of a separation between user needs and currently pursued research. We are optimistic for the future, since research approaches to home system integration and to light automation and intelligence are gaining momentum, and we advocate, for the years to come, an ever increasing involvement of users in designing the homes of tomorrow.

Poll results (available at the `http://elite.polito.it` web site) can be freely exploited for further research or they can be used as pre-test investigations for devising sound and extensive surveys on specific aspects of Human Home Interaction.

References

[1] J. S. Armstrong and T. S. Overton. Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 16 (August):396–402, 1977.

[2] E. J. Baur. Response bias in a mail survey. *Public Opinion quarterly*, Winter:594–600, 1948.

[3] C. Berg. *Bringing Technology Home: Gender and Technology in a Changing Europe*, chapter A Gendered Socio-technical Construction: The Smart House. Buckingham: Open University Press, 1994.

[4] J. Bohn, V. Coroama, M. Langheinrich, F. Mattern, and M. Rohs. Social, economic and ethical implications of ambient intelligence and ubiquitous computing. In E. Aarts (Eds.) W. Weber, J. Rabaey, editor, *Ambient Intelligence*, pages 5–29. Springer, 2005.

[5] Dario Bonino, Emiliano Castellina, and Fulvio Corno. The DOG Gateway: Enabling Ontology-based Intelligent Domotic Environments. *IEEE Transactions on Consumer Electronics*, 54/4:1656–1664, 2008.

[6] G. Conte, D. Scaradozzi, A. Perdon, M. Cesaretti, and G. Morganti. A simulation environment for the analysis of home automation systems. In *Proc. Mediterranean Conference on Control & Automation MED '07*, pages 1–8, 2007.

[7] Diane J. Cook, Juan C. Augusto, and Vikramaditya R. Jakkulaa. Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, Volume 5, Issue 4:277–298, 2009.

[8] G. Demiris, M. Rantz, M. Aud, K. Marek, H. Tyrer, M. Skubic, and A. Hussam. Older adults' attitudes towards and perceptions of "smart home" technologies: a pilot study. *Medical Informatics and the Internet in Medicine*, 29(2):87–94, 2004.

[9] Berry Eggen, Gerard Hollemans, and Richard van de Sluis. Exploring and Enhancing the Home Experience. *Cognition, Technology and Work*, Volume 5, Number 1 / April, 2003:44–54, 2003.

[10] Ame Elliott. Flamenco image browser: using metadata to improve image search during architectural design. In *CHI '01: CHI '01 extended abstracts on Human factors in computing systems*, pages 69–70, New York, NY, USA, 2001. ACM.

[11] Michael Friedewald, Olivier Da Costa, Yves Punie, Petteri Alahuhta, and Sirkka Heinonen. Perspectives of ambient intelligence in the home environment. *Telematics and Informatics*, 22:221–238, 2005.

[12] I.A. Group. Scenarios for ambient intelligence in 2010. Technical report, IST, 2001.

[13] Sumi Helal, William Mann, Hicham El-Zabadani, Jeffrey King, Youssef Kaddoura, and Erwin Jansen. The Gator Tech Smart House: A Programmable Pervasive Space. *IEEE Computer*, 0018-9162/05:64–74, 2005.

[14] C. Mayer and R. Pratt. A note on nonresponse in a mail survey. *Public Opinion quarterly*, 30:646–667, 1966.

[15] Jan M. V. Misker, Jasper Lindenberg, and Mark A. Neerincx. Users Want Simple Control over Device Selection. In *Joint sOc-EUSAI conference*, pages 129–134, 2005.

[16] Donald A. Norman. Technology First, Needs Last: The Research Product Gulf. *ACM Interactions*, XVII.2:38–42, 2010.

[17] Uta Priss. Faceted information representation. In *Proceedings of the 8th International Conference on Conceptual Structures, Shaker*, pages 84–94, 2000.

[18] S. R. Ranganathan. *Colon classification: Basic classification*. Asia Publishing House, 1960.

[19] Carsten Röcker. Perceived Usefulness and Perceived Ease-of-Use of Ambient Intelligence Applications in Office Environments. In M. Kurosu, editor, *13th International Conference on Human-Computer Interaction, HCII 2009*, number 5619 in LNCS, pages 1052–1061. Springer-Verlag Berlin Heidelberg, 2009.

[20] G. Sacco. Uniform access to multimedia information bases through dynamic taxonomies. In *Proc. IEEE Sixth International Symposium on Multimedia Software Engineering*, pages 320–328, 2004.

[21] Fritz Scheuren. What is a survey. Technical report, American Statistical Association, http://www.whatisasurvey.info/, 2004.

[22] Ali A. Nazari Shirehjini and Felix Klar. 3DSim: Rapid Prototyping Ambient Iintelligence. In *Joint sOc-EUSAI conference*, pages 303–307, October 2005.

[23] E. Suchman and B. Mc Candless. Who answers questionnaires? *Journal of Applied Psychology*, 24 (December):758–769, 1940.

[24] B. C. Vickery. *Faceted Classification*. Rutgers University Press, 1965.

[25] R.W. White, B. Kules, S.M. Drucker, and M.C. Schraefel. Supporting exploratory search. *Introduction to Special Section of Communications of the ACM*, 49, Issue 4:36–39, 2006.