The Map as a Tool for Identifying Pervasive Interactions in Today's Home

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Abstract. The task of making the spectrum of home network connections visible in its entirety and details is a necessary first step towards a renewed understanding of home and domestic life as well as of the technical systems that underpin it. This paper proposes the categorization of pervasive interactions that take place in contemporary living spaces through certain criteria and tries to map them into the predefined spaces of today's home, by creating a basic visualization tool. The research concludes with an example of a "composite map" that shows all the interlinked interactions that take place in a contemporary home. This map can become a potential tool for further research in the fields of the structure, behaviour and countenance of home networks, of advances in intimate media, applications and networked devices, and of augmented architectural spaces that interact with complex and pervasive communication networks.

Keywords: Home mapping · Pervasive computing in architecture · Home automation · Automation control

1 The Networked Home

Home as a space – both the architectural envelope and the spatial configuration of objects or devices of daily use and personal value – is the material testimony of the identities and the habitual acts of its inhabitants. Modern home, was based on a functional division of internal space. Its roots date back to the 17th century rise of the bourgeois class in Europe, which signified a gradual evolution of a room-to-function correlation. Gradually, bourgeois homes became an agglomeration of rooms highly specific for their function (bed-room, living-room, play-room, bath-room, etc.). The specific function of each room was reflected in the furniture, equipment and decoration it had, as well as the engendering of it. The function of each room dictated a certain protocol of its usage (e.g. one can use it certain time of the day) and a certain behaviour (when in bedroom, wear robe) [1]. The division of home-space, primarily by function, is certainly a western practice. In different cultures, home-space is divided according to family hierarchy or structure or division between genders. The architectural space of

home reflects the functional structure of it, and the relations of rooms reveal the structure and sequence of everyday life.

Current living trends however, augmented by wireless connectivity, suggest that the inhabitants of today's contemporary homes are largely investing personal time and value on the data connections taking place within and through their homes, a practice that can alter the "traditional" functions and rooms of "modern living". These connections become an increasingly important part of daily home-life routines catering for the inhabitants' "networked living demands" and contribute equally to the establishing of the person's or the household's social position within a larger but usually geographically distributed social circle. Yet most of these connections remain invisible – operating at the background – or difficult to trace or relate spatially in contrast to social and cultural theories that emphasize on mundane tasks as a means to understand everyday life [2].

Following previous work on mapping pervasive interactions in a home environment [3], this paper proposes the categorization of pervasive interactions that take place in contemporary living spaces applying certain criteria and tries to map them into the predefined spaces of today's home, by setting up a basic visualization tool according to current living trends. The interactions identified, based on wireless or conventional network communications within and through home-space, are categorized relatively to their basic attributes such as parties involved, purpose or goal, nature of data exchanged, exclusivity, result/effect, time/duration/reoccurrence, and others. These interactions include the documentation of trivialities of everyday life (e.g. monitoring of activities), the documentation of domestic based big data (e.g. monitoring and of household objects, data from sensing devices), the formation and presentation of identity (e.g. consciously projected data about home and inhabitants). Using this categorized list of network activities, we apply both quantitative and qualitative criteria in order to identify the most probable, common and important interconnections in a contemporary home. We regard that the task of making this spectrum of home network connections visible in its entirety and details is a necessary first step towards a renewed understanding of home and domestic life, as well as of the technical systems that underpin it. Of course the contemporary networked home is closely intertwined with parts not geographically linked to it. Communications between transport media and the house, between houses in a neighbourhood are a few connections that take place and influence domesticity. However, due to publication limitations we chose to present findings for home as a closed networked ecosystem, while all outgoing network activity is treated simply as a route to the internet to dens and gather information.

1.1 The Scenario

This paper is presenting the outlines and first findings of an ongoing speculative design experiment. The team's initial aim was to use a real living scenario, where activities and network functions would be mapped, and investigate methods of home network

representations. For this purpose, we decided to involve only existing technologies, devices and today's living activities. Therefore we carried an initial research looking for networked appliances, devices, and objects as well as related applications for domestic use, that are commercially available.

We also decided to use as our testing environment a type of house that complies with the current European standards for average household (members and size). According to official statistics the average European household is 2.4 members [4], which means that families consisting of a couple alone, or with one child are considered typical of today's European societies. Moreover, the average European house occupies an area of approximately 120 sq.m., and has 4 main rooms (presumably: living-room with kitchen, 2 bedrooms, and bathroom).

This design experiment could have been based in an existing real household, and a real family, monitoring its life and environment, and visualising its networking activities. However, we deliberately chose to use for our scenario (as a background) a specific visionary architectural project of the 1950s, importing from it the architectural environment, and the explicit lifestyle of the (supposed) inhabitants, that could actually fit into the typical requirements set by the average European household. The project we used is "The House of the Future" [5], or HOF in short, by British architects Alison and Peter Smithson, designed and constructed in 1955-56 as a show-piece for the "Ideal Home Exhibition" organised by Daily Mail in Olympia, Kensington, London, UK (Fig. 1). This concept house was furnished and equipped with several innovative items and technologies (some existing as mock-ups). There are several aspects of the HOF that are of great interest today. It was a hypothetical arrangement of a house in 1980. The fluid architectural interiors and the lack of doors is quite reminiscent of today's homes or loft houses.

For the needs of our project we re-furnished this concept house with a new inventory consisting of networked items and several applications that would cater for the everyday life of a couple and renamed our project "House of Today" (HOT). This new inventory is superimposed to the existing household. Furthermore, we were inspired from the rich photographic material depicting casual activities inside the house in order to create simple narratives that would engage the pair of characters inhabiting the house into daily routines. Such narratives involve waking-up and breakfast, preparing dinner, or other activities.

In short, for our mapping experiment we created a hypothetical scenario based on real data. This enabled us to project a more complicated picture that would heighten the issues we would like to investigate. More than that, we found that the dialogue between the old concept-house with its retro-futuristic aesthetics and the visualizations of the new networked inventory, proved quite suggestive and at times ironic.
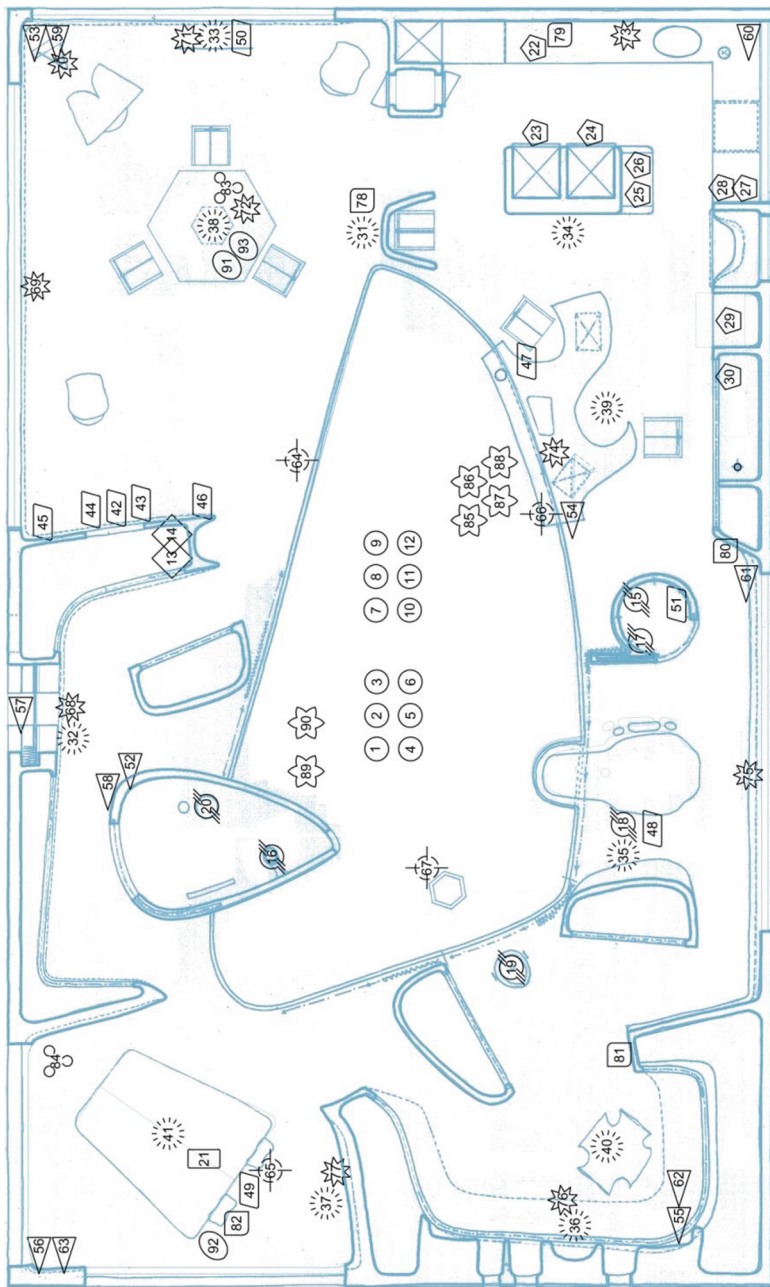
Fig. 1. Plan of the House of Today (HoT) with full inventory (No. 1-93). Each family of devices (e.g. wearable, kitchen, sleep, bath, surveillance, etc. is depicted with a dedicated symbol and a specific number, corresponding to the number in Table 1.

1.2   The Household Inventory

Home automation is receiving a renewed attention from companies producing networked devices and objects, mainly due to the rise of IoT, the evolution and widespread use of smart devices like smartphones and tablets as well as numerous applications developed for them [6, 7]. A quick survey showed that most of the available devices and applications relate to the automated and remote home control. John Thackara [8] back in 2001 has highlighted that "we are designing a world in which every object, every building—and nearly every human body—becomes part of a network service" which we will bequeath to next generations without having fore-thought the effects this will have on the quality of life. Thackara illustrates his critical vision with an example: "Ericsson and Electrolux are developing a refrigerator that will sense when it is low on milk. Imagine the scene. You'll be driving home from work in your car, and the phone will ring. "Your refrigerator is on the line," the car will say. "It wants you to pick up some milk on your way home." To which my response will be "tell the refrigerator I'm in a meeting."

Apart from home automation, connected devices available in the market tend to follow a few other trends, focusing around other areas concerning domestic and personal life, such as health care, health monitoring, body caring, security and surveillance, connectivity, advice on cooking or other domestic tasks, energy consumption monitoring and generally environmental awareness.

In our hypothetical scenario we have selected a number of commercially available connected devices to make the inventory of the HOT. The couple of inhabitants – for the needs of our experiment we named them Anna (A) and Paul (P) – have (hypothetically) selected the devices described in Table 1. After having compiled the detailed, itemized list of the hypothetical household inventory of connected devices in the HOT, we assigned a unique identification number and a dedicated position for each item inside the plan. Each device is placed in its appropriate place on the house plan (Fig. 2) with an indication of its respective number distinction in the graphic sign for each device was made.

Table 1. List of connected devices in HOT

Id No.	Function	Device - description	Link
1	Wearable	Apple watch	https://www.apple.com
2		MC10 adhesive wearable	http://www.mc10inc.com
3		Ampstrip adhesive heart rate monitor	http://www.ampstrip.com/
4		UP24 Jawbone activity tracker	https://jawbone.com

(*Continued*)

Table 1. (*Continued*)

Id No.	Function	Device - description	Link
5–6		2 × WeMo keychain sensor (P + A)	http://www.belkin.com
7	Portable	Apple iPhone 6	https://www.apple.com
8		Apple iPad Air 2	
9		Apple MacBook Air	
10		Nokia Lumia 930	http://www.microsoft.com
11		Nokia tablet 2520	
12		Toshiba Tecra w50-a	http://www.toshiba.eu
13	Hubs	Smartthings hub	https://www.smartthings.com
14		D-Link Wireless N300 ADSL + 2 Gigabit Cloud Router	http://www.dlink.com
15	Bath	Eva showerhead	http://evasmartshower.com
16–19		4 × Dornbracht smart water (WC, shower, bath, washbasin)	http://www.dornbracht.com
20		Toto Intelligence Toilet II	http://www.toto.com
21	Sleep	Luna mattress	http://lunasleep.com/
22	Kitchen	LGThinQ refrigerator	http://www.lg.com
23–24		LGThinQ ovens	
25		iDevices kitchen thermometre	http://idevicesinc.com
26		Crock-Pot 6 Slow cooker (WeMo)	http://www.crock-pot.com
27		Mr. Coffee Smart optimal brew (WeMo)	http://www.mrcoffee.com
28		iKettle	http://www.firebox.com
29–30		LGThinQ Washer & Dryer	http://www.lg.com
31	Climate control	Nest thermostat	http://www.nest.com
32–37		6 × Sensibo A/C control (living, kitchen, bath, dressing, bedroom)	http://www.sensibo.com
38–41		4 × Haiku ceiling fan (living, bedroom, dressing, kitchen) with senseme connected to nest	http://www.bigassfans.com

(*Continued*)

Table 1. (*Continued*)

Id No.	Function	Device - description	Link
42	Electronics/media	Sony Bravia android TV	http://www.sony.com
43		Sony 4 K media player	
44		Sony HiRes Music Player	
45–49		5 × Sonos Play: wifi speaker (living, kitchen, bathroom, bedroom)	http://www.sonos.com
50		WD myCloud Mirror NAS	http://www.wdc.com
51		iShower	http://idevicesinc.com/ishower/
52–56	Surveillance/security	5 × Withings Home camera (entrance, living, kitchen, dressing, bedroom)	http://www.withings.com
57		august smart lock at entrance	http://www.august.com
58-63		6 × WeMo room motion sensor (entrance, living, kitchen, bathroom, dressing, bedroom)	http://www.belkin.com
64–66	Sensing	3 × netatmo indoor weather station (living, bedroom, atrium)	https://www.netatmo.com
67		netatmo rain gauge (atrium)	
68–77	Lighting	10 × hue personal wireless lighting bulb (entrance, 4 × living, kitchen, bath, dressing, bedroom))	http://www2.meethue.com
78–82	Smart sockets	5 × WeMo smart socket (living, kitchen, laundry, dressing, bedroom)	http://www.belkin.com
83	Robots	irobot Roomba 880 vacuum cleaner	http://www.irobot.com
84		Karotz toy robot (living)	http://store.karotz.com
85–88	Plants	4 × Click&Grow smartpot (herbs)	http://www.clickandgrow.com
89–90		2 × Parrot flower power (atrium)	http://www.parrot.com
91–92	Miscellaneous	2 × Fireside smartframe (living, bedroom)	http://www.fireside.co
93		Nimbus dashboard (living)	http://www.quirky.com/shop/596

1.3   Interactions and Connections

Normally, households comprise of people, animals (pets), objects (stuff) and territory (property land or space). Among those, humans tend to have the dominant role. Although inert things and the environment do have agency over the household, this is not active or purposeful. Augmented technologies provide composite things that are active and responsive and have a high or low reasoning. The current study is based on the idea that humans are among several quasi-equal parties within the as an eco-system. The parties involved into most augmented home interactions are the following:

- person: (PE) any human, owning, having access and agency over the household, occupying the home, or connected to it remotely or not.
- pet: (PET) autonomous real or virtual organism (other than human) belonging or connected to the household. Autonomous robots belong to pets.
- agent: (AG) software-based self-learning organism, physically or not manifested, that compliments home functions and environment. Remotely, or not, connected to the house. Agents can manage, facilitate, or even represent the house.
- node: (ND) mediating device, facilitating communication between parties.
- device: (DEV) complex machine/appliance/gadget with both a physical and an electronic component that performs specific tasks.
- application: (APP) software, with only an electronic component that performs specific tasks.
- object: (OB) physical object belonging to the household (this is not interactive unless it has a tag or becomes a device)
- tag: (TAG) electronic device attached to other parties (hosts) (persons/pets/nodes/devices/objects) that performs specific tasks (identification, geo-location, etc.)

These individual parties can team together in order to form composite entities. Although most of the above parties can irrespectively conjoin in order to form composite entities, (PE + DEV, DV + ND, OB + TAG, PT + AG, DEV + APP + ND, etc.) some of the combinations seem to have specific relevance and can be named as distinct types. Some of these are analogous to traditional parts of a home. For example:

- house: (HOU) The complete list of parties comprising the household joined together forms the house. The house can interact as an entity with all parties.
- room: (RO) A portion of the house (not necessarily a spatially defined portion) that supports a person or a set of activities, or has specific access rules or ownership. This can interact independently to house.
- routine: (ROU) A cluster of entities that are normally interconnected in order to fulfill specific activities, tasks, rituals, e.g. "making breakfast".
- face: (FA) Face refers to clusters of entities working together in order to edit and project images of the house (or parts of it) to the outer world, social media, etc. (projecting identity). It is a public face and can deal with social communication.
- fence: (FC) A virtual structure comprising of several parties (objects, devices, agents, etc.) that limits access or cuts off specific connections. Example: "energy waste fence", "private data fence".

- vigilant: (VG) A composite party that monitors and warns about unwanted or potential threats, misbehaviours, ill-judgments, hazards, etc. Can be simply an agent, but in most cases is a combination of sensors, applications and devices.
- hearth: (HRT) More contrived and significant than a room, it is a place for the valuable(s) and a source of energy. Can be about safeguarding as much as for sustaining. Contains what makes sense to be bequeathed to next generations. Perhaps the entity which is about history, memories and traces of the past.
- depot: (DPT) less complicated than a room entity, with a specific function to store (and archive) data, archives, etc.
- other types of home entities may emerge.

2 Living Activities and Actions

Home, whatever form it takes, is the basis for fulfilling fundamental human needs for living, such as providing shelter, a place for rest and comfort, a place to store and protect possessions and, among others, a place to nurture oneself and family. Following Philip Agre's work [9] we have identified two different aspects of living and categorized them into activities and actions. To clarify this distinction, activities relate to the broad organization of human doings, such as sleeping or working, while actions explain specific procedures for doing things. Both of these concepts are dynamically interrelated to each other, meaning that any activity can be influenced by, as well as influence any action. For example, one can make food to eat, while her eating experience can modify her process of making food. Moreover, the relation between them can, over time, turn habitual, causing certain combinations of actions and activities to become the "unconscious" base for other, newer, more conscious activities [10, 11]. A behaviour can transform into a habit at any given time, as well as evolve and become more complex. Its identification is important for our work, as it has immediate effects on the visualization tools that we propose: new habitual series of actions can be represented and selected as a group.

By studying the interactions and connections that were described in the previous chapter (4), we have arrived at a set of activities and actions that can accommodate most of them and these are depicted in Table 2 and are used throughout our proposed visualizations at the following chapter. If we take the sleeping activity as an example, the following interrelations can occur between the actions in Table 2 and the list of devices in Table 1:

- We organize ourselves for sleep, through routines such as turning off the lights. This can be completed automatically through the WeMo motion sensor in the living room, when it does not sense anyone there, or the nest thermostat in conjunction with the Philips hue lights.
- We consume less energy when we to go to sleep. The nest thermostat learns our patterns and knows when we're sleeping to reduce heating and consequently energy consumption.
- We can make a hot milk to help us go to sleep and the iKettle can have it ready at the optimal time

- We reproduce sleeping patterns and the Luna mattress identifies them and informs us.
- We protect ourselves before we go to sleep (locking doors through the august smart lock and our phone).
- We can evolve our sleep by introducing white noise through an app in our smartphone and make it play through the Sonos wireless speakers
- We react to sleeping by waking up, preferably using the jawbone
- We can learn of sleep deficiencies and correct them via the www on any compatible device.
- We can buy (monetary exchange) a better pillow for a better sleep at any e-shop.

Table 2. Activities and actions in home living

Activities of home living	Actions for home living
Eating - Drinking	Organizing
Sleeping	Consuming
Hygiene	Making
Studying	Reproducing
Leisuring (oneself)	Maintaining/Protecting
Entertaining (others)	Evolving
Intercommunicating	Reacting
Extracommunicating	Learning
Working	Exchanging

3   Proposed Visualisations - Conclusions

Mapping activities inside the typical bourgeois western house, is almost like reading the plan, for each room is named and furnished according to its function as described before. In today's home, there are functions, aspects or activities superimposed onto the typical bourgeois-type functions. These functions, activities, actions, and several composite entities taking part in the home connections network, require a more complex and multilayered set of visualization and mapping techniques, as well as viewpoints. An initial survey on home network visualizations has been presented in previous work [3]. In this phase we initiated this design experiment and tried to create examples of how the specific home's network would be visually presented. Several views were considered: Dashboard view, Activity view, Action View, Immersive view, Accumulated view, and others. In the following Figs. 2, 3, 4, and 5 we present a few. This design experiment is in progress.

   These initial visualizations were discussed among several people. This first evaluation revealed several basic issues:

1. Since the media that these will be probably shown in will be either smartphones or tablets, having relatively small screens, the density of information and of the graphics does affect the degree of comprehension of the home network. The more

Fig. 2. Dashboard View: Persons and Devices are shown. [07:32 am: Anna is waking up]. Active connections are shown in bright yellow lines, previous connections in orange and pending or anticipated connections in purple. To the right, there is information about current connections. Scrolling around with finger on screen, devices inform about their status. Map is shown in a tablet interface.

Fig. 3. Immersive View: Connections and devices are shown over the image of the real space. All other relevant information can be added to the layout. The image is shown in a smartphone interface.

Fig. 4. Action View: All available actions are displayed with icons. To the right the inhabitant can review details about current actions, as well as forthcoming ones. The network connections are shown in the style of recommendations between devices and actions, as well as details on near future actions.

Fig. 5. Activity View: This view monitors specific living activities throughout the house by showing simple on/off functions of specific devices linked to the selected activity. For example for a sleeping activity the refrigerator goes into away mode, the washer and dryer start their operation, A/C units are shut down, along with lights, motion sensors and the door is locked.

dense the information and the graphics, the more difficult is to read and discern. On the contrary, less information and simpler graphics tend to result in fragmented concept of network.

2. A "technical" style of visualizing information about home activities, is evaluated as non-appealing to the more intimate nature of home everyday life. We were encouraged to consider more personified graphic layouts.
3. Reading information about network connections with the home plan makes it easier to localize spatially the events, but creates visual clutter. A simpler and more intuitive way is perhaps necessary.

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