Poster: Everyday Interaction With Autonomous Internet of Things

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Abstract

This research seeks to investigate the design of interaction mechanisms and user interfaces for a future Autonomous Internet of Things (A-IoT). Recent studies examining the real-world acceptance of a IoT systems (e.g smart thermostat) highlighted how errors, limited legibility, lack of accountability of the ownership, intent and excessive user expectations caused frustration and abandoning of the technology. These findings suggest that the design of A-IoT systems needs to address several challenges to be made accountable; including, on the system side, designing autonomous decision-making to take into account the uncertain nature of contingent human behaviour; and on the user side, the need to make these systems legible and usable in everyday life. Our goal is thus to establish the scientific underpinnings of user interactions with A-IoT systems, in a domestic everyday context, with the aim of elucidate the aforementioned challenges.

1 Introduction

An Autonomous Internet of Things (IoT) or A-IoT actively manages data and decisions on behalf of users, using robust machine learning techniques and optimisation algorithms. Recent studies [Yang and Newman, 2013; Yang *et al.*, 2014] examining the wide acceptance of commercial smart thermostats, which learns to autonomously control central heating systems based on the presence of users and their activities, highlighted how system aberrations, limited legibility of the system operation and mismatch of user expectations frustrated some users who went on to abandon the technology altogether. [Alan *et al.*, 2014] has shown that users distrusted a potential smart energy infrastructure due to lack of accountability of the ownership, intent, and permitted activities of the autonomous technology. Thus, A-IoT system needs to address several issues to be made accountable. These include designing autonomous decision-making to take into account the uncertain nature of contingent human behaviour and the need to make these systems legible and usable in everyday life.

2 Background

Research on human interaction with autonomous systems, dating back to the 1980s [Wiener and Curry, 1980], has concentrated mostly on the context of safety critical systems and applications for expert users. These include avionics [Wiener and Curry, 1980] or air traffic control [Parasuraman *et al.*, 2000] which proposed a framework to inform automation design, taking into account human-automation interaction. However, central emphasis was placed on human performance metrics, not applicable to domestic practices, in these earlier works. As autonomous and connected systems become increasingly available for personal and domestic applications in everyday settings, the focus needs to shift from performance metrics to qualitative methods to study the ways in which AI enabled automation may be developed, adopted and integrated into domestic practices, or rub up against them: a gap this research aims to fill. Recently, researchers started to address the opportunities for smart and autonomous technology at home. In particular, attention focused on the smart thermostat, given the associated opportunity to reduce energy, cost and carbon emissions, and the relatively simple actuation. Most of the published work [Lu *et al.*, 2010; Scott *et al.*, 2011; Shann and Seuken, 2014] focused on addressing the technical feasibility of algorithms and systems to drive smart thermostats, without evaluation of actual deployments and user adoption. Fewer prior contributions report studies of actual usage of autonomous appliances in the wild. [Yang and Newman, 2013; Yang et al., 2014] report users frustration, as mentioned above. Prior work around energy consumption and laundry practices [Costanza *et al.*, 2014] explored reactions to envisaged smart grid scenarios, where autonomous systems mediate users interaction with domestic energy. Such scenarios were presented as animated whiteboard sketches in environment workshops. Participants interviews revealed the needs and opportunities for human interaction within the design of autonomous energy systems [Rodden *et al.*, 2013]. Furthermore, field trials were conducted to expose participants to actual prototypes of autonomous energy

systems through a combination of sensing technology and study financial incentives where participants of ordinary homes were augmented to believably simulate future smart grid scenarios (e.g., with autonomous washing machines and tariff-switching agents). The results indicated that specific interaction design features can positively influence users adoption of the technology, and its integration within existing daily routines [Alan *et al.*, 2014; Costanza *et al.*, 2014]. The proposed research in this paper, builds on these findings with the aim to extend their contribution by including the user-centred, iterative design and prototyping of A-IoT systems in the research process, and in this way learning more general design principles. For this research we propose to extend the application of A-IoT to a broader range of domestic practices, involving goods as well as services, enabling us to design and study more general user interaction techniques with A-IoT systems. Moreover, we proposed to broaden the emphasis to interactions with external entities, leveraging mechanisms from game theory and multi-agent coordination.

3 Opportunities for A-IOT

Rather than focus on IoT artefacts (the things), our emphasis is on the everyday activities as they are implicated in and the human practices involved in these activities and how these are part of the broad ecological arrangement of the home. To achieve this ambition, we consider the particular domestic endeavours:

- Food practices which foreground contingencies in the process from purchasing of raw ingredients to the assembly and consumption of meals.

Our focus on domestic food practices builds upon existing work in HCI [Gao et al., 2012; Hupfeld and Rodden, 2012] and offers a rich and challenging scenario for technological intervention, due to the complex combination of factors that influence food choices. Arguably, from a consumers perspective, domestic food practices are dependent on a multitude of contingent concerns, such as what is in the fridge or cupboard, what is needed to make a meal out of it, what does the rest of the family want to eat, and when do they get home so that dinner can be made. Specific dietary requirements can also further complicate the matter. Moreover, food provides a useful focus for the study of autonomous systems given that a number of existing services and practices around food involve different forms of agency delegation such as ordering take-away food rather than cooking. To make our findings more general, we also focus on domestic cleaning practices and associated resources (detergents, utensils, appliances...). Cleaning routines involve a different set of appliances and utensils, and embody different values and needs (e.g. skin allergies to dust or specific cleaning chemicals). Existing cleaning practices often also involve agency delegation (e.g. to a cleaner, or to a commercial laundry), negotiated distribution of chores among household members, and an increasing amount of technological automation, from smart washing machines to several vacuuming robots already on the market. Ethnographic studies of how householders manage contingencies within domestic practices will enable us to design novel accountable interaction techniques with A-IoT systems that can be appropriated in everyday practice.

4 AI for Automating IoT

On a more technical level, an autonomous software agent associated to a specific household will model and infer the specific schedules of the occupants and their preferences for certain types of products and activities. Based on the ability to update over time, the agent will represent the households in online markets to purchase goods, schedule their automated delivery for specific household members, and even autonomously carry out domestic tasks (in our studies this will be simulated through existing services). Such decisions will aim to minimise cost and waste. Moreover, such agents representing multiple households will be able form collectives to take advantage of buying in bulk from suppliers and effectively strengthen their position in the supply chain. Hence, we will investigate game theoretic mechanisms that will ensure that the negotiations between agents and humans in online marketplaces result in social welfare maximising outcomes. Specifically, we will employ cooperative game theoretic techniques to inform the creation of purchasing groups in on line supply chains via the construction of incentives that ensure resources and rewards are fairly allocated among the members of the groups. Finally, by automating purchasing decisions, it will be possible to account for real-time changes to deliveries and cancellations due to contingencies and changes of plan. For example, an autonomous order for perishable items would be automatically and transparently transferred to a neighbour for a discounted price. Therefore, we will investigate planning algorithms that will aim to optimise the schedule of agent and human activities under uncertainty created by contingent human activities. More importantly, we will develop algorithms that internalise human input such that the plans generated are acceptable and controllable by humans (e.g., ordering food or booking cleaning sessions based on predicted needs).

4.1 Essential Autonomous Ordering:

Essential autonomous ordering investigates challenges in relation to anticipated need both in terms of ethnographic studies to understand existing planning practices as well as the development of A-IoT prototypes to explore autonomous ordering and scheduling of delivery. This phase will focus on the autonomous ordering of cleaning goods and non-perishable food (hence limiting requirements of the system in terms of time constraints), based on sensing and inference of the level of stock available in the home, and opportunities for autonomous group buying. Emphasis will be placed on deriving principles for the provision of collaborative human-agent mechanisms, for example to engage users in providing data for food packaged in non-traceable forms, or annotating data about domestic activities [Costanza *et al.*, 2012].

4.2 Taking Everyday Contingencies into Account:

The research focus will be extended to give more emphasis to time-related constraints and changes of plans that affect the users schedule. In addition to levels of stock available at home, we will monitor users locations and calendars to model their schedule and autonomously order take-away food, or ready meals, to simulate future smart food preparation appliances. We will complement this by investigating the delegation of cleaning chores to autonomous agents (simulated through e.g. commercial laundry services or crowd-sourced tasking systems such as TaskRabbit), informed by IoT sensors (e.g. augmenting laundry baskets so that they automatically schedule a laundry pickup when full) and the handling of contingent events (e.g. spillages).

4.3 Autonomous Negotiation for Supply Networks:

This will be the final phase of the research and it will build on phases 1 and 2 to explore the full vision of an autonomous supply and distribution network. Autonomous orders from each home agent will be broadcast to a market of suppliers, to look for the best way to fulfil them through autonomous (or semi-autonomous) negotiations. We will additionally take into account the origin of food items (e.g. is it seasonal Was it grown sustainably Does it support the local economy Is it within the acceptable cost level), and introduce collaborative mechanisms to absorb contingencies and exceptions, including those motivated by monetary transactions (e.g. transfer a pre-order no longer wanted to another local consumer for a fraction of the cost or selling unused cleaning products bought in bulk) and other sharing mechanisms such as gifting (e.g. because too much was made, or because it is easy to make extra) or renting ones cleaning appliances (e.g., pressure washer or carpet cleaner).

5 Planned IoT Deployments

The purpose of this research is to understand how household members interact and experience a future A-IoT in their everyday life, particularly this will help to design interactive mechanisms that works on behalf of users in an accountable way, and understand people's perception of a shopping list suggested by a system. Finally, this could help to understand how a system like this can contribute to more sustainable choices in everyday food purchases through awareness of food consumed.

6 Proposed Domestic IOT Setup

To facilitate the research objectives two Home Essentials system, which helps to track products and gain a better understanding of the lifecycle of groceries or essential items at home, are currently being developed for deployment.

6.1 Bar code scanner

Internet enabled enabled barcode scanner (bluetooth barcode scanner connected to internet through user mobile) used to scan groceries in after purchase of groceries, and then scan items out when finished or throwing in the bin.

Study:
Primilnary study with 15 participants given barcode scanner to gather data underway.

6.2 Smart Kitchen Scale

Internet connected scale continuously monitors consumption of item placed on scale. Users can set threshold of when to re-order or be notified in advance if the item is about to run out.

Study:
15 participants each given 2 scales each underway.

7 Conclusion

The purpose of the research if to highlight the importance of the human factors in design of autonomous IoT Systems. Although the primary focus of the research is related to food practices the objective of the overall research is to learn how human interactions can influence AIoT systems and what factors need to be considered to design successful and user adaptable A-IoT Systems.

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