New Directions for the IoT: Automate, Share, Build, and Care

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ABSTRACT

As the IoT is taking hold in the home, in healthcare, factories, and industry, new challenges and approaches arise for HCI research and design. For example, HCI is exploring agency delegation and automation to support the user in managing the deluge of IoT data, make decisions, or even take actions on behalf of the user, while economic models are being proposed to drive sharing economy

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services. This creates new problems including how to design appropriate solutions for uncertain and dynamic human behaviour, how to ensure resources are distributed fairly, and how to ensure that the user can understand system actions and ultimately remains in control. These issues are becoming more pertinent as the IoT diversifies into safety-critical domains such as manufacturing and healthcare. This one-day workshop intends to bring together the CHI community to explore the interactional, socio-cultural, ethical, and practical challenges and approaches that these new domains raise for the IoT. With this, we want to consider how such approaches could be integrated to achieve more sustainable, inclusive, or effective interactions.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing**;

KEYWORDS

proactive technology; autonomous agents; internet-of-things; autonomy; sharing economy; healthcare

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INTRODUCTION AND SCOPE OF THE WORKSHOP

The connection of everyday objects with the digital world has moved forward swiftly, and technologies available today enable the "ubiquitous computing web", where the Internet of Things (IoT) is the predominant paradigm [9]. Industry has paid considerable attention to the IoT for its potential economic impact on new mechanisms for remote monitoring, control detection, and use of data as a service for new business models [15]. IoT design will gradually leverage techniques from the field of robotics, creating the IoT objects that react to users in various ways, including movement. Recently, even minimal movement of an abstract non-humanoid robotic object has been shown to provide social cues in the context of greeting [2]. The IoT paradigm is now moving to a next level, where in addition to the actual sensing and monitoring capabilities new approaches are needed to more effectively deal with the deluge of data generated by the IoT, and to design appropriate IoT technologies for diversifying domains. This is the moment that this workshop is inspired by.

This workshop seeks to bring together HCI researchers, designers, and industry practitioners that push the boundary of IoT-based research and design; in particular we are interested in novel environments and domains for the IoT, as well as new approaches for the design, development, and control of the IoT applications and services. For example, the connected objects may now include rules

Case Study: Home Essentials. Through the tracking and prediction of the lifecycle of essential household goods with an IoT probe, researchers identified everyday contingencies that shape consumption in the home [7]. For example, the household's routine changes and sporadic events (such as guests visiting) are factors that are difficult to predict from a system's perspective, yet they should be taken into account in predictive systems designed to complete a particular task such as automatically reordering items. The lessons learnt in a domestic context reveal how everyday contingencies could impact the delegation of tasks to an automated system. If we focused our analysis on more critical contexts such as factories or healthcare, the contingent practices this would probably reveal new challenges for predictive approaches in these domains.

Inspired by the case study, we seek to discuss concerns and solutions around ethics and privacy of the use of consumption data in contemporary society, i.e. by supermarkets. If a system has enough accurate information to nurture a model about items bought, brands, and particular time of consuming of items per household, it is possible to generate a set of patterns about each household i.e., frequency of vegetable consumption (i.e. how healthy is this family), how much alcohol the family consume per week (i.e. how unhealthy is this family). All this could lead to biased categorisations that affect people, for example if this data would be shared with insurance companies.

and basic learning processes to perform some tasks on behalf of humans, based on more advanced processing of sensor data, actuating change and working autonomously as a result. This Autonomous Internet of Things (A-IoT) is just one example, albeit a key one, of new approaches to the IoT. The A-IoT includes as key features automation, autonomy and delegation of tasks [1], and this raises new challenges for both application domains and approaches that this workshops seeks to discuss. As IoT technologies are increasingly used and adapted to everyday environment, we elicit some exemplary domains and approaches in the following to inspire potential participants to take part in our workshop.

From home automation to the sharing economy

The home environment is an established domain that has been studied to understand how everyday practices impact the interaction between users and the IoT. For example, a study by Yang and Newman reflects on how a commercial "Learning Thermostat" to control heating does not take into account the collaborative practices at home, leading to a lack of understanding of how the system works, and to negative user perceptions [25]. The delegation of agency from users to A-IoT systems has been investigated by focusing on food practices, Verame et.al suggest that delegating agency on which food items to order must be warranted and is subject to constraints for the items to be integrated successfully in people's food consumption practices [22]. The side bar presents a further research case study of IoT in the wild, with research conducted to illuminate the challenges potential predictive systems may face in the light of the uncertainty of human behaviour.

Agency delegation can involve direct financial implications, e.g., a smart electricity meter that automatically switches energy supplier based on users past consumption, as well as tracking and prediction of activities in the home, and could help save money on energy bills [1]. Similarly, IoT applications around grocery shopping (e.g. where sensors are used to keep track of how much is consumed, and how much is left in the pantry) have potential to reduce food waste, and help consumers coordinate group orders, saving both on retail prices and delivery costs. Scenarios in which financial decisions are delegated to autonomous IoT systems are also supported by the simultaneous rise in popularity of technologies such as cryptocurrencies and smart contracts. This may lead to scenarios where shopping and financial decisions may be mediated by autonomous software agents [19].

However, while smart and A-IoT systems should be expected to work seamlessly most of the time, it is also likely users will occasionally face glitches, due to incorrect predictions. Such glitches may be caused by limited data sets, biases and noises in real-world data, and limitations of computational models. The financial implications would be that users would end up paying more for their energy, or their grocery shopping.

THEMES AND GOALS

We aim to explore socio-technical challenges that have emerged from existing designs and studies, and further explore how future technologies might rise to broader socio-economic issues. We invite contributions including, but not limited to the following topics:

- What can be learnt from the emergent use of IoT in new domains?
- Techniques for interacting with—and making sense of— the autonomous IoT
- Ethical considerations and privacy issues in relation to user data in the IoT
- Visualisation of configured devices and collected data to support user understanding and interactions
- Approaches for studying and delivering IoT technologies sustainably within the sharing economy
- Environmental and socio-cultural challenges for design, adoption, interaction, and engagement with IoT

ORGANISERS

We draw upon a range of people with prior experience of organising IoT-related workshops: **Carolina Fuentes** is a Research Fellow at the Horizon Digital Economy Research Institute, and in the Mixed Reality Lab, at the University of Nottingham. Her research has focused on human-computer interaction, tangible user interfaces and pervasive healthcare (informal caregivers and dependent elderlies). Her current work explores the internet of things in home environments, autonomy of IoT, and ethics and privacy in different IoT scenarios. She has experience designing and developing prototypes to evaluate in the field with end users to identify impact and implications.

Therefore, we are interested in issues of technology adoption and trust around IoT systems that support the delegation of financial decisions. Several studies indicate that people's approach to everyday financial decisions often goes beyond simple profit maximisation, and a complex network of emotional factors and cognitive biases come into play [13]. The design of interactions around IoT systems that make financial decisions on behalf of their users, then, should take account of such studies, and more in general of the findings and research methods of disciplines such as Behavioural Economics [13] and Behavioural Game Theory [4].

Factory and industry

Factories and industry settings more broadly (e.g., workspaces, retail, office settings) are a key new domain for the IoT, creating value on the operation optimisation, making predictions about maintenance, inventory optimisation, automated checkout in retail, energy management, and productivity improvements [15]. In these large-scale scenarios, new questions about the IoT capabilities will emerge, moving from single-pre programmed functions to more autonomous and flexible behaviours to relieve human management of those devices. In the construction industry, simulations that use all the data collected by IoT sensors on construction machines have been investigated to automate the decision-making process to control the operation [14]. The idea is to include unpredictability, specificity of projects, and the complexity of processes to help humans to interpret this data (ibid.). Moreover, human-robot team collaboration will have its space in factories and industry scenarios [24], raising pertinent questions for HCI and Human-Robot Interaction research to understand how to design for challenges such as security, trust, engagement and usability. The HCI commumity will need to adopt new approaches to study and design for this space that blurs the lines between IoT and robotics.

Healthcare

IoT in the healthcare context has created many opportunities and has the potential to support care practices within and beyond the hospital to improve patient care [10]. In the hospital environment, IoT is facilitating remote health monitoring [10], identification of adverse drug reactions [12], and new innovative ways to engage with patients during the hospital stay [23]. In the home setting, IoT is enabling patients to collect real time data about their condition [11] in order to increase health awareness [21] and support treatment (e.g., smart pillboxes and automatic medication reminders) and the communication between the hospital and the home [10].

However, most IoT systems have mainly focused on tracking data of patients in real time through different devices connected in a network [9]. Although this is considered an advantage because it could improve the efficiency of care, reduce cost and promote a permanent contact between patients and healthcare providers [9], there are many opportunities that can be explored through the adoption of IoT to reshape healthcare. For example, the data collected through different sensors could be used to

Martin Porcheron is a researcher in the Mixed Reality Lab. His work empirically examines how people embed the use of technologies such as smartphones and 'smartspeakers' within settings such as pubs and the home. He has recently co-organised workshops at CHI '16 and '18 [18, 20], and CSCW '16 and '17 [6, 17] on topics including collocated interaction and conversational interfaces.

Joel E. Fischer is Assistant Professor at the School of Computer Science where he teaches Design Ethnography, and member of the Mixed Reality Lab at the University of Nottingham. His practice-focused research in collocated interaction has been published at CHI, CSCW, UbiComp, ECSCW, and he has previously co-organised related workshops at Ubicomp [5], CHI [20] and CSCW [17], on topics including IoT and voice-controlled interactions.

Enrico Costanza is Associate Professor at the UCL Interaction Centre. His research lies at the intersection of design and technology and it is influenced by behavioural and social sciences. His current focus is on designing systems that can help people make sense of data (e.g. from the IoT) and on interaction with smart and autonomous systems in everyday situations.

Nervo Verdezoto is is an assistant professor at the Department of Informatics, University of Leicester. His main research areas include HCI, CSCW and Digital Health. His work has investigated the challenges and opportunities to support medication and self-monitoring practices of older adults. His current work explores how technologies shape pregnant women's experiences, clinical encounters and decision-making. He has worked in several research projects related to healthcare, physical computing, and sustainable HCI. He has co-organized workshops for NordiCHI, ECSCW and CSCW.

support a sort of "independent" behaviour. The main challenge is to design for uncertainty situations, uncover and anticipate the possible dangers for using IoT in unpredictable ways, and identify which critical tasks could be delegated in this context, and which behaviours would be delegated in a system where a minimal error could have a critical impact. A baby's breathing tracker that won't alert at the right time, or a "smart" insulin pump [26] that misunderstands external signals are potentially life-threatening errors. These errors can affect the acceptance and adoption of IoT systems in healthcare as technologies can have positive or negative effects not only in people's care practices but also into their everyday lives [16]. Understanding who controls the technology or the level of control retained by the system [8] as well as designing for appropriation, for continuity, understandability and learning [3] have important implications for the design of future IoT systems in healthcare.

WORKSHOP ORGANISATION

We propose a one-day workshop to present, reflect on, and enrich participants' work-in-progress. As such, we are purposefully seeking submissions of work at a variety of stages, ranging from published through to 'unfinished' projects. Based on prior experience of organising a range of workshops at different venues, we propose the following activities for the workshop. A website will be set up at iotdirections.wordpress.com, which will be used to promote the workshop by publishing the call for participation and submission details online.

Pre-Workshop Plans

The call for participation will be distributed to relevant academic mailing lists and through the organisers' existing social networks (e.g. via Twitter). We will also actively solicit submissions (via personal contacts and targeted invitations) from a broad range of researchers and practitioners whose work relates to the workshop topic or who can make a significant contribution to the workshop.

Potential workshop participants should submit a 3–6 page position paper (including references) describing their interest and/or previous work related to the workshop. We will select papers based on: a) relevance to the workshop, b) quality of the submission, and c) the diversity of the participants. We will limit the size of the workshop to 20–25 people to ensure effective discussion.

All selected papers will be available online on the website prior to the workshop, and participants will be expected to read all accepted submissions ahead of the workshop to help ground the discussion.

Workshop structure

We will structure the workshop into four activities: introductions and ice breaker, a topic-sorting exercise, roleplay breakout groups, and ultimately a plenary.

Introductions and ice breaker: We will commence our workshop with a ice breaker followed by a round of brief presentations and discussions from participants. This will enable all attendees to

Valeria Herskovic is an associate professor at the Department of Computer Science, Pontificia Universidad Católica de Chile. Her research is the areas of HCI and health informatics, especially focused on older people and people with low digital skills in Chile. She also co-organizes the local women in computing conference, Chilewic.

Oren Zuckerman joined IDC's school of communications in 2007, after completing his PhD at MIT Media Lab. He founded IDC's Media Innovation Lab, developed the Interactive Communication program in the school's BA program, and received several research grants in the field of HCI, Social Robotics, and learning technologies. His research areas include non-humanoid robotic objects and tangible interfaces for learning.

Leila Takayama is a cognitive and social scientist, who studies human-robot interaction. In 2016, she joined the faculty at the University of California, Santa Cruz, as an acting associate professor of Psychology. In 2016, she also founded Hoku Labs to do human-robot interaction research consulting for product teams. Her work lies in the intersections of ubiquitous computing and embodied cognition.

acquaint themselves with each others work and background. Participants will be asked to include what they are bringing to the workshop as well as what they hope to take away from the day. This opening session will be designed to be fast-paced, with participants asked to make post-it notes on topics, questions, and ideas throughout the presentation and discussions for later ideation activities.

Topic sorting and group formation: We will use the post-its to engage in an interactive affinity diagramming-esque session, focusing on identifying the core areas within the presented topics. Given our broad workshop aim to explore *new directions for the IoT*, this activity will allow us to situate and explore specific directions based upon workshop participants' areas of work. The exercise will be scaffolded to encourage participants to form together into groups to support later workshop activities. The size of groups will be constrained to 4 or so attendees, preferably including one workshop organiser, and so the number of groups will depend upon attendance.

Breakout roleplay: Prior to an afternoon slump setting in, breakout groups be tasked with creating and enacting a scenario that illuminates the design and benefits of IoT (or *disadvantages of a poorly designed IoT setup*) in a chosen setting. Groups will be given free reign on what or how to design the performance, and will be provided with a minimal set of materials (e.g. paper, pens, and other basic stationary). For example, groups could choose to take a provocative approach to highlight ways in which the IoT might cause problems if poorly designed, or they might choose an interactive approach whereby the audience could be involved as a specific autonomous agent that does things throughout the performance or acts as other participants in a shared economy. We will faciliate this session and encourage attendees to include ideas from the their own work.

Plenary: All groups will deliver their respective performances to each other during a plenary, with a discussion being structured around the topics, issues, and ideas following each group. As our workshop proposal is broad, the goal with this exercise is to provocatively identify new and challenging socio-technical issues, thus discussions could include ideas around how to achieve adequate sensing, measurement, actuation, autonomy, and the shared economic factors.

Post-workshop plans

Dependant on the outcomes of the workshop, an ideal outcome might focus on the development of a *Communications of the ACM* article (or equivalent) that synthesises and brings to the fore and discusses the various new directions in which IoT is being drawn, and how HCI researchers and practitioners can rise to ensuing challenges.

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CALL FOR PARTICIPATION

This one-day workshop brings researchers together to explore the interactional, sociocultural, ethical, and practical challenges the IoT raises in under explored domains, and exchange insights on new approaches to IoT, including models from economics, agents and autonomous systems, collaborative aspects, and how these approaches could be integrated to achieve more sustainable, inclusive, or effective interactions. We seek to continue a dialogue with a futuristic vision about the new directions of the IoT, sharing design ideas and examples. As part of this, we will try to identify new challenges and possible scenarios that blur the lines between IoT and robotics. Interested participants should submit a 3–6 page position paper in the CHI Extended Abstracts format (incl. references) describing their ongoing work related to the workshop including, but not limited to:

- **empirical research** on the study of IoT in relation to automation, economics, and manufacturing
- **methods and approaches** for studying the use of interaction with IoT

We will select papers based on: a) relevance to the workshop, b) quality of the submission, and c) the diversity of the participants. We will limit the size of the workshop to 20–25 people to ensure effective and focused discussion in the second and third parts of the workshop. At least one author of each accepted position paper must attend the workshop and all participants must register for both the workshop and for at least one day of the conference.

More information about the workshop, organisers, and submission is at iotdirections.wordpress.com.

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