Things That Twitter: Social Networks and the Internet of Things

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Abstract. In this paper we investigate on the potential of combining social and technical networks to collaboratively provide services to both human users and technical systems. In the Internet of Things (IoT), things talk and exchange information to realize the vision of future pervasive computing environments.
The common physical and social space emerges by the objects' ability to interconnect, not only amongst themselves, but also with the human beings living and working in them.
In this paper, we report on a use case of a distributed sensor-actor environment in which both humans and technical systems together form a socio-technical network.

1 Introduction

Social networks serve human needs: by updating a status description on Facebook or sending out a tweet, users can let their network of friends - or even the digital public - know what is happening in their lives. Moreover, videos, pictures, or also news and links get spread by a few mouse clicks. Currently, Facebook receives 55 millions of manual updates by 350 millions of users worldwide [1].

People's personal relationships become more manageable and live on more actively also over distance through the instant updates by the participants of the network. Yet another perspective of social networks is that people's personal relationships become more visible and quantifiable than ever before: friends get counted, can be organized in groups, friends of friends can be browsed and compared to ones own.

But people do not only share relations with friends, they also have relations to things, to beloved books, movies, gadget, items, products, food, cars etc. There are applications emerging allowing us to share details of the catalog of books we own [2] or just anything in our possession [3].

Simultaneously, the emerging Internet of Things bears products and things that start communicating their status and functionality as well. The washing machine twittering when it has done its job [4], the stereo telling the world about the music you are listening to, or the mobile phone announcing the calls you have made recently [5].

With this paper, we want to foster the discussion about the implications of socio-technical networks in the context of the Internet of Things.

The paper is structured as follows. In Sec. 2 our motivation and idea for combined social and technical systems is described. We introduce, in Sec. 3, the CognitiveOffice as an example environment and highlight the potential of socio-technical networks. In Sec. 4 we discuss the implications of socio-technical networks as introduced in the use case scenario. We conclude the paper by summarizing the contributions and give an outlook on future research in Sec. 5. The related work is discussed in the individual sections.

2 Socio-Technical Networks

Technological networks, such as distributed wireless sensor networks (WSNs) or complex modern robots, share data to accomplish dedicated tasks by exchanging, assessing and processing information from various heterogeneous sources and make their data available to other systems. Kingsley [6] investigates how the relationships, processes and the flow of information between people, physical objects, "and the environment will make implicit information explicit and engagement between the physical and the digital more commonplace".

The idea of the Internet of Things (IoT) [7] is linking digital information to a network and thereby relating digital information to real world physical items. While many terms have been used to describe the vision of seamless information access, exchange and manipulation, the IoT can become a daily reality by the adoption and deployment of more and more networked objects [8]. The impact thus is not only achieved by communication but by cooperation.

Bleecker [9] states that "As more smart, mobile, sensing 'Things' are attached to the Internet, their presence and participation and agency can be felt in our online lives (2nd Life)" and asks "If the social web (the Internet of Social Beings) greatly impacted our social lives, how will an Internet of Things be felt across our lived experiences?". While he focuses on what such a social web might look like when network connected 'Things' participate, we focus on what the technical systems can themselves participate in socio-technical networks. Three motivations guide us here: First, networked objects exchange data amongst themselves to perform their dedicated tasks. Second, this data usually is invisible for human users, thus leading to incomplete or missing mental models of the connections and dependencies between all the little helpers invisibly and calmly integrated in our pervasive computing environments. Third, there is a plentitude of information, even in little text messages, humans exchange, such as Tweets on Twitter. Why should our smart objects not also use this information, too, and thus be part of *our* world and network as well?

3 The Cognitive Office - An Live-In Office Environment

3.1 Twitter and Tools

While Twitter itself is only intended to post short messages, so-called tweets, many tools exist to visualize the topics and contents that are broadcasted. Examples are Neuro Productions' 5K Twitter Browser [10] or Neofomix' Twitter StreamGraph [11].

Solis [12] discusses online social networks regarding the implications of the connections made visible by "connecting" in the various communities. He argues that a parallel world, a network "where individuals not only connect with those they know, but also with those who are interested in following their online activity, and not necessarily with the expectation of reciprocation." This could also be said about a technical publish/subscribe type of network where various sensors and actuators post their state.

Therefore, we have chosen to use Twitter as an example online social network and created plugins (publishers/subscribers) that post the events from selected sensors to Twitter and listen for Tweets themselves from devices they are interested in. "Twitter is a free service that lets you keep in touch with people through the exchange of quick, frequent answers to one simple question: What's happening?".This is pretty much what listening devices are, too. In our example, the state of some twittering plants have been imported and the states of e.g. the windows and doors of the CognitiveOffice have been tweeted. The example of a twittering plant will be discussed in more detail below. To build up the technological network it is required to make use of a middleware.

3.2 Robot Operation System for "Smart" Environments

The concept of ImmoBots [13] is to view "sensor rich, massively distributed, autonomous systems" that pervasive computing environments are as immobile robots. As middleware is still an open issue for complex, heterogeneous, distributed sensor-actor systems in the field of pervasive computing, we decided to take something that is available, open source and community supported by researchers from the robotics domain.

It was shown [14, 15] that robotic middleware can be successfully used to provide context awareness in pervasive computing environments, such as kitchens. While here the Player/Stage middleware was employed, we decided to investigate ROS – Robot Operating System – as alternative and potential successor to Player in our experimental setup.

ROS allows two main ways of exchanging data: services with defined request-response messages and so-called topics, where data is exchanged via a publish/subscribe architecture where processes make data available and other processes are free to enlist for data updates. Figure 1 shows a subset of the data exchanged via the publish/subscribe scheme.

Figure 2 shows an early visualization of the Cognitive Office in the 3D visualizer Gazebo which is connected to ROS. Different areas of interest (two tables with dedicated chairs) and a shelf are depicted. If activity is sensed, e.g. by analyzing the chair's activity and finally the seating position of its user, this is visualized. If items are taken or placed in the shelf, e.g. by capacitive sensing [16] or by detecting the (dis-)appearance of RFID-labeled items, this is also incorporated and used to complement the overall activity recognition processes.

The system incorporates end user devices like the Skype tangible user interface used in the ubiquitous presence system [17], and also embedded sensing

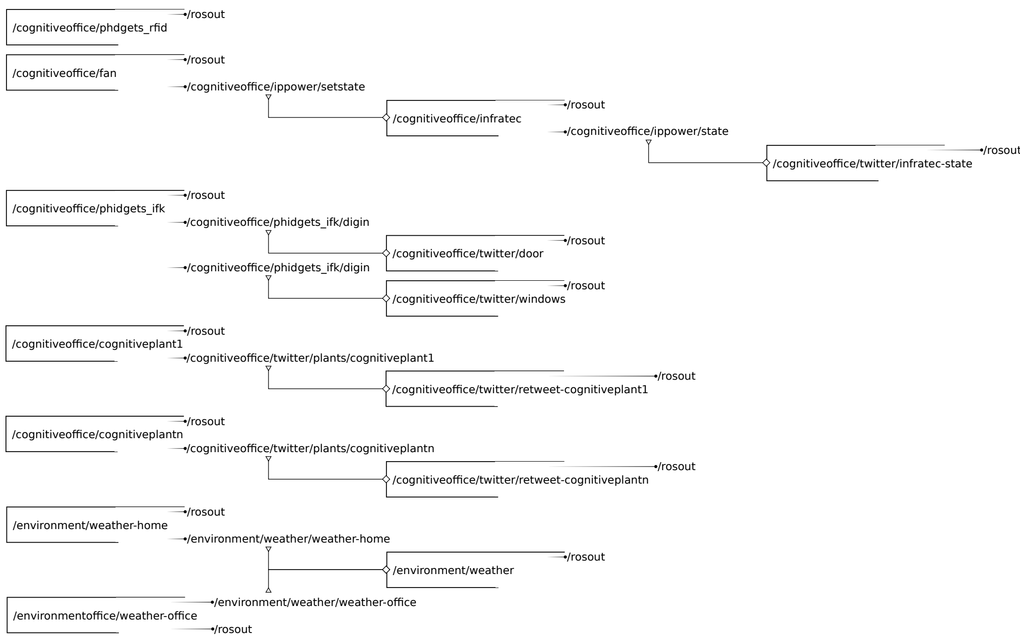


Fig. 1. CognitiveOffice: ROS Topics and Connections. Especially event-based data streams are published when they occur. A Twitter-feed listener (/cognitiveoffice/cognitiveplant1) for example checks for posts and feeds them into the middleware (bottom left).

systems in everyday objects like coffee mugs (Fig. 3). The CognitiveMug is a sensor augmented mug, similar to the MediaCup [18]. The CognitiveMug is used for activity recognition, too, but it extends the MediaCup in that it is mainly used to augment environmental sensing for robot-object interaction: Several physical phenomena are hard or impossible to perceive by e.g. ceiling mounted camera systems, such as the temperature of the contents, the fill state or the usage history, e.g. if the mug is still clean or has been used. Additionally it keeps track of when and how often it is used. Location here has been left intentionally underspecified to mainly look at (dis-)appearing events - in a shelf, the dish washer or on the user's desk on his coffee mat, using RFID as identification technology. This is similar to the tracking of goods where only key points (entering or leaving a warehouse) are of importance w.r.t. location, but the transport history (e.g. gravity exerted during transport, or temperatures experienced).

An example use case for the CognitiveMug would be to detect the lifting of the cup, then measuring the coffee temperature and, via the middleware, asking for an visual or acoustic warning to prevent the user from accidentally drinking cold coffee, which from his/her preferences is known to be not desirable.

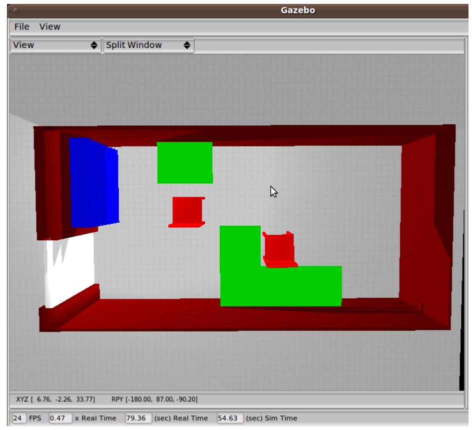
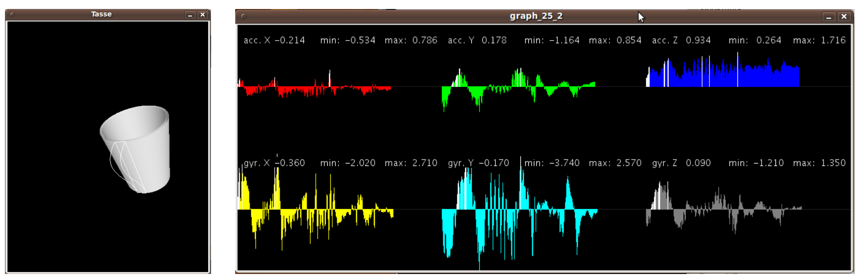


Fig. 2. CognitiveOffice: 3D Visualization and Simulation with Gazebo and ROS



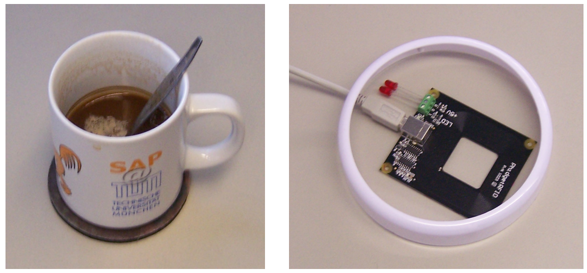
(a) CognitiveMug: 3D Model

(b) CognitiveMug: Graph

Fig. 3. Caption of subfigures (a), (b)

Without a sophisticated location system, objects cannot be tracked and traced. But not for all types and objects this is meaningful. As for a shelf it is enough to know when and what item has been taken, it is enough for a coffee mug to know when it has initially been placed on its mat. This allows to observe usage (drinking) patterns and finally to provide services to both the user of the office and to others as well, e.g. by generating presence information when actions have been detected. Yamada et al. [19] have shown that it is possible to infer activities based on only looking a selected spaces. The coffee mat is similar to the beer mat by Butz et al. [20]. A typical mug mat and the RFID reader integrated in the opened mug mat used in the CognitiveOffice are shown in Fig. 4.

In the next section, we will exemplary describe two controllers using the various sensor streams of the networked objects and how they cooperatively communicate over various networks to perform services on behalf of the human user.



(a) Coffee Mat: Non-digital coffee mat.

(b) CognitiveMug Mat: RFID reader augmented coffee mat to detect and track coffee mug usage.

Fig. 4. To prevent the table from getting spoiled, mats are used. This everyday behavior can be traced using RFID enabled devices.

3.3 Perception-Cognition-Action Loops

Cognitive Objects are extending and leveraging the existing research on smart objects. Up to now, research focused mainly either on activity recognition or on the interaction. Cognitive Objects extend these two approaches by incorporating knowledge on the individual objects purpose, characteristics and parameters, and collaboratively exchanging information over various networks.

Cognitive Objects are obtained by either prototyping [21], restriction, modification or extension of existing everyday objects [22]. We expect Cognitive Objects to significantly extend the PCA loops by providing in-situ knowledge about the object itself, its purpose and its physical and digital parameters.

We give two simple examples of so-called PCA (perception-cognition-action) controllers to illustrate the potential of mixed socio-technical networks.

Cognitive Plant Controller Plants inhibt social spaces, indoors and outdoors, and are often our room mates in office environments for they are green, improve air quality and are nice to look at. Though, they are often not cared about enough, so they commonly die sooner or later. Projects like Koubachi [23] or Botanicalls [24] support us human care givers with technology to achieve the social goal of caring for your plants.

In the following, we use two plants equipped with a Twitter-enabled sensing system called Botanicalls [24]. This open source software and hardware platform twitters the humidity information directly to the plant's twitter account. By following the tweets of your plants, you can keep yourself informed about the health state of the plants. In our use case, this is especially useful as the plant is located on top of a high shelf and its moisture cannot be measured by simply sticking a finger inside the soil.

The PCA loop implemented is as follows: The plant's tweets at `http://twitter.com/Botanicalls0191`. These tweets are imported into the ROS middleware by a Python script that regularly checks the Twitter account for updates. On updates, they are published into the middleware. Another process with the plant's preferences on sunlight, moisture and temperature recognizes the environmental changes. It polls a daylight service giving the current's daylight length (by polling information from Weather Underground, the CognitiveOffice's indoor temperature (from environmental temperature sensors) and the plant's moisture from Twitter. All this information from various physical and virtual networks is incorporated and evaluated. During e.g. winter, this controller asks an IP based power switch to turn on an UV light source to ensure enough light for the plant. If e.g. the windows are left open for too long, a notification is sent on behalf of the plant to warn the office user. By closing the loop from sensing, sense making and actuation across several networks, combining social networks and technical networks, the collaborative goal of plant care is achieved and the borders between physical and virtual worlds diminish.

Cognitive Fan Controller Another example for a simple PCA controller is the fan controller. By querying RSS weather data for the office location, the indoor temperature measurements and the information about the open-close-state of the windows, it proactively perfroms services for the office users. In summer, when the temperature is high during the day, the news feed announces sinking temperatures at night and when the window has been left open, the fan proactively circulates air to not annoy the user with the noise of the running fan. During the day, the fan starts breezing when the user opens the door e.g. to leave for lunch or when he is away for a meeting.

More elaborate controllers have been deployed for e.g. presence detection, ranging from keyboard and movement activity and the incorporation of calendar information, or for a warm coffee have already been deployed. Other examples also include smart white board cleaning robots, controlled by computer vision, that learn when the white board can be cleaned, take a picture prior to cleaning, and then over night remove the contents of the white board so the user can use it for fresh ideas in the morning.

The ROS middleware here enables the continuous addition of novel devices and services, both in the digital and physical world. Thereby the vision of an Internet of Things is gradually achieved more and more with each newly connected pyhsical thing or virtual process.

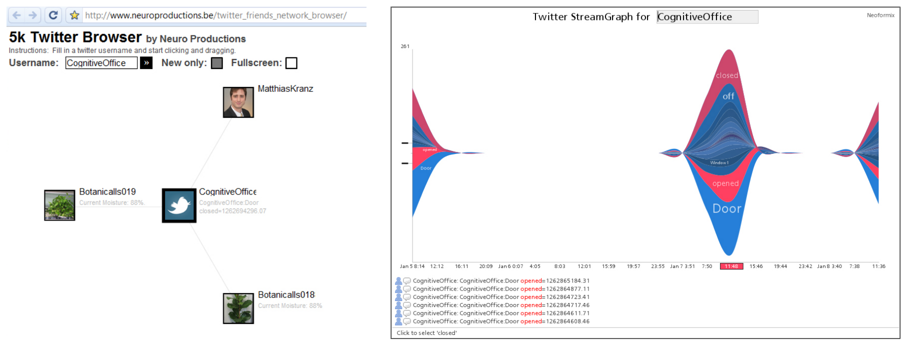
4 Implications of Socio-Technical Networks

We have shown that the convergence of social and technical networks in the context of the Internet of Things lets the borders between both worlds vanish even more. Not only become things networked, but they become a part of our daily lives.

Twitter is one example of social community networks. The goal of using these networks to bring people together e.g. by using Twitter to keep the relatives of a patient informed during the operation[3].

[3] http://scienceroll.com/2009/01/19/twitter-live-surgery-sugarstats-and-100-ways-for-hospitals/

By extending social networks with technical networks, e.g. in the field of ambient assisted living or independent living, the environment can keep the relatives informed if e.g. the relative has fallen or if he has eaten his meal.



(a) Twitter: Network Connections between the physical and virtual users of the CognitiveOffice [10].

(b) Twitter: StreamGraph visualization using Neofomix' tool [11]

Fig. 5. Local sensor and social web data are merged.

In Fig. 5(b) (a) the connections between the twittering plants, the environment and the office user is shown, selected real tweets of the environment are shown in Fig. 5(b) (b). Using a well-known platform allows a user to understand the otherwise only virtual connections between devices and services and to visualize them.

In the case of the example office scenario, the most prominent events are the entering and leaving of guests, but also the window usage. These events, without visualization, would have otherwise gone unnoticed and thus the actions taken by e.g. a related learning algorithm would have not been easy to understand by the (external to the digital system) human observer. Generalizing for other intelligent environments, combining technical and social networks allows the reusage of prior understanding and knowledge of the human user and to inform him on what is happening - which was the motivation of using Twitter, as we have introduced it in the beginning of this section.

Based on these first findings we are looking forward to investigate together with the other workshop participants further ways of breaking down the various borders between digital and virtual systems in the Internet of Things which is more and more becoming part of our daily lives.

5 Conclusions and Future Work

We have demonstrated a social network not only connecting humans to each other but also things to human:

– We "fuse" the first, real *and* second, virtual world
– We close the loop by combining sensing *and* cognition *and* actuation
– We combine simulation *and* real world data in the middleware
– We include local sensor data from the environment and smart objects *and* remote network data from social networks

We see the presented system as a research vehicle to assess the implications of socio-technical networks in the context of Ubiquitous Computing and the Internet of Things, especially regarding the perception of these system in the eyes of human users. The context of a real, used, shared and inhabituated office environment by both digital and physical beings and systems provides the basis for various other research in specific domains. Parts of the presented scenarios maybe applied in the field of independent living and smart home environments targeting at assisting non-scientific users in their daily routing. We believe that the Internet of Things, as it becomes part of our social lives, can help non-technical experienced users to better understand the socio-technical relations we continuosly establish in a more technical advcanced society and make our dependencies on systems more transparent and intuitive, e.g. using the notion of relationships to things as depiced by Twitter tools.

As part of future research, we will set up a second scenario in the context of an ambient assisted living project where heterogeneous distributed sensing and actuation systems will use Twitter to both inform the inhabitant and their relatives about on-going tasks and activities. We plan to additionally include wearable sensing systems to monitor personal health data and complement the environmentally sensed activities.

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