Cooperation and Competition in the IoT Sandbox

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ABSTRACT

In a connected world with systemic relations and complexity, design needs new methods and approaches to create and design for systems that grow dynamically, relate to human users or inhabitants temporarily or over time, and expand their capabilities with emerging technologies. The openness of such systems challenges designers and conventional design approaches. The IoT Sandbox is a novel design environment that allows individual designers and design teams to experience and create given synthetic, adaptable constraints of a scripted system—through cooperation and competition. The IoT Sandbox exists in conceptual, physical and networked space, clearly linked to an educational methodology. We showcase this system in a group design project that targets a smart home design space, and we conclude the paper with a discussion of our findings and position for future work.

CCS CONCEPTS

• **Human-centered computing** → Interaction design.

KEYWORDS

Growing Systems, IoT, IoT Sandbox, Design method, Cooperation, Competition

1 INTRODUCTION

Systems and systems thinking are widely recognized as the next challenge for (interaction and product) design (e.g., [2, 4, 6, 8–10, 12]). While there is consensus on the necessity to turn towards systems and systems thinking in design, what is considered a system depends on discipline, abstraction level, application area and other criteria [7, 12]. In this position paper we focus on systems of connected and interactive products in the home (Home IoT), and we operationalize systems as networks of distributed, interactive products (artifactual nodes) with multiple users (human nodes). These nodes are connected to each other in various ways: wires, radio waves, sensing modalities, and even social cues. Consequently, the systems that we focus on are both technological as well as social constructs that follow the rules of both [4]. In this definition lies an extension to the common understanding of the Internet of Things: connected technologies help us form systems of more or less complex nodes that exhibit agency and engage in interactions. Furthermore, we understand such systems to be dynamic not only in their component-specific and systemic behavior, but also in their

composition: (artifactual) system components can be added, discarded or replaced, firmware is regularly updated, and people may join or leave. We characterize such dynamic systems as 'growing systems' [4] to indicate that the system's user experience co-evolves with the users to match their preferences or other requirements. The result of this 'growth' is that systems of products exhibit systemic openness: their functionality changes over time and is not completely determined at the time of the design. Designing with and for these systems is the core challenge that is targeted in this paper.

Despite the natural affinity of design to complexity and the openness of systems, we observe a gap in design research and practice when it comes to designing for systems beyond the conceptual. The openness of systems challenges the design as their conventional approaches often do not work. Here we focus on two aspects of systemic openness, (1) distributed scope and interaction and (2) functional composition. Looking at the functional scope, standalone interactive products have clearly demarcated physical and interaction boundaries. It is clear where they start and end, which opportunities for accessing functionality through interaction they offer and how many users are involved to access this functionality. Systems of products do not have these clear boundaries; they may flexibly extend to the currently active products in the system. Second, a system's composite functionality changes with its structure. The functionality depends not only on the functionality of the individual products in the system, but also on functionality that emerges as part of the system, that is, functionality that different individual products can only offer together or in interplay. This form of emergence is partly undetermined and open at the time of design, challenging the designer to deal with a multitude of dependencies in the design process that can only be resolved through a dual perspective on product and system level–this is what we refer to as systemic openness. Systemic openness is a particularly wicked phenomenon [11] to deal with in industrial design processes. Connected products and systems have been part of educational curricula since the conception of ubiquitous computing. What strikes us as interesting, particularly when exploring the body of work from design and computer science departments is that the 'things' that feature are centered on the singular artifacts without explicitly discounting the optionality of connectedness and, in principle, open functionality. However, the system perspective as an equal perspective in design is not fully explored. There are other approaches to involving connected things in design such as connectivity-inspired service design workshops [1] that aim to find solutions to contemporary issues in the domains of smart cities and mobility, clean energy transition and social networks. While these approaches take a holistic view of a system, they neglect the individual artifact and its embedding in the human context through interaction and meaning. We observe that the exploration of new

educational approaches towards systems and systemic openness is still in its infancy. In our approach, the introduction of the systems design challenge into an educational context begins with the realization that students need to be sensitized for dealing with systemic openness and complexity in their collective design activities, that concepts like emergence and growth set this challenge apart from 'conventional' interactive product design challenges. This requires new tools and methods for design. In this position paper we present the IoT Sandbox, a platform that fosters a systemic perspective in the students that work with it. In what follows we first present the IoT Sandbox, then we show a brief design case after which we conclude with a discussion and a position for future work.
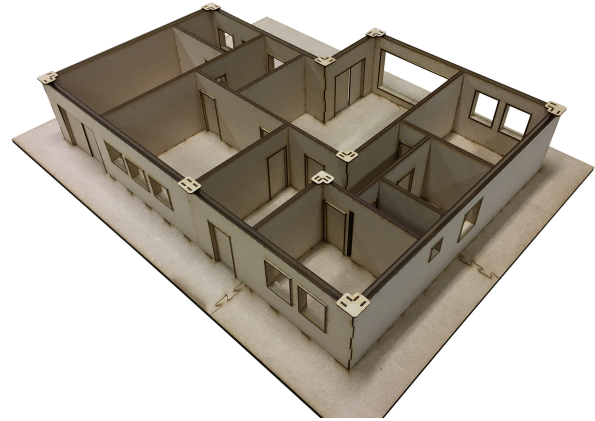
2 THE IOT SANDBOX

The IoT Sandbox builds on more than a decade of experience with teaching design students to design connected and smart products in a growing systems context. We first summarize our experiences briefly after which we present the IoT Sandbox together with methodological considerations.

2.1 Building on experiences in education

Over the past decade we have introduced the systems perspective to our Industrial Design students. This has been an insightful journey where we have learned about the difficulties in adopting a systems perspective in design. One of the main hiccups proved to be systemic openness, students have consistently struggled with the lack of boundaries (or constraints) that was caused by the concept of systemic openness. A persistent tendency in our students was the desire to 'think the solution through' rather than to start making solutions: the mind was trusted over the hands. Even more than for traditional design endeavors, this approach is bound to fail for systems and even more so as the system is not static but evolves dynamically through the designing and acting of others. Consequently, this created long unproductive struggles that took up significant time in the semester, designerly exploration suffered. Another prominent observation was that students created 'walled gardens' that reduced their design solutions to essentially interaction design solutions rather than 'systems' design solutions–data, connectivity, emergence or openness were markedly scarce in the solutions that the students delivered. After all, designing systems is not compatible with a divide-and-conquer approach or mindset—and the same holds for teaching how to design for systems. So, we conceptualized the IoT Sandbox.

2.2 The IoT Sandbox

The IoT Sandbox turns the act of designing for systems into a systemic activity itself. It explicitly limits designing in compartments. With the IoT Sandbox we took both pragmatic steps towards lowering the technological threshold as well as methodological steps helping with taking a systems perspective. Physically the IoT Sandbox is a 1:20 scale model of a family home [3] that acts as an arena for design to explore, share and evaluate systems behavior, see Figure 1. Together with the home we introduce 'mundane characters': ordinary, everyday (but imaginary) people that live in the house as a family. The connectivity layer of the IoT Sandbox is provided by a design middleware [5] to lower the threshold of prototyping with

Figure 1: The 1:20 scale model of the home as the physical layer of the IoT Sandbox.

connected technologies and sharing data. To aid in taking a systems perspective we have implemented two rules (1) all students share the same reality and (2) all students need to find ways to connect their designs to the designs of their fellow students. This sets the stage for two social mechanisms that work to our advantage in tackling the systems design challenge: cooperation and competition. Part of the game is that students cooperate over the borders of their (group) projects. They cooperate through exchanging (sensor) data in order to elaborate the connected and systemic nature of their design proposals. The students compete for (conceptual and physical) space in the IoT Sandbox. This element of competition is implemented for two reasons: (a) Students are instilled with a sense of urgency – if they do not choose a spot in the IoT Sandbox they might not be able to do what they want (there is only one reality, no two versions of the same concept are allowed). This sense of urgency helps speed up the process and makes students make design decisions. (b) Students need to creatively solve 'conflicts' between functionality of different projects and necessarily take a systems perspective in their designs. A last (but seldom used) mechanism is given to project coaches: if the projects in the IoT Sandbox are evolving towards too reduced interaction design challenges, coaches can make interventions in the home, for example by adding a mundane character to the house and shake up the design space.
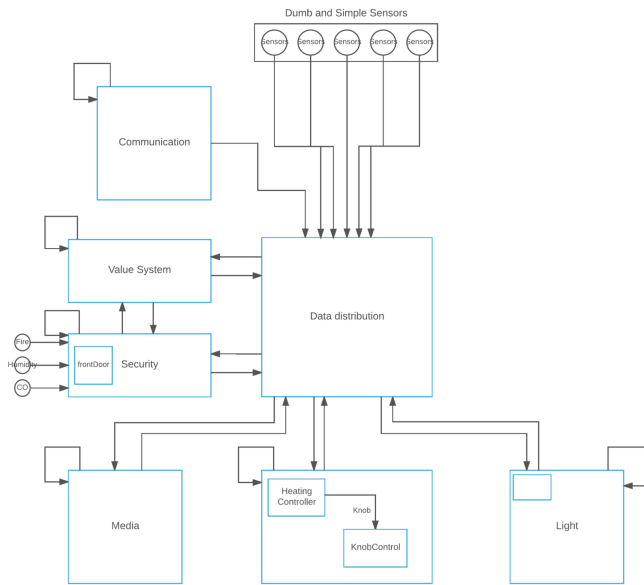
In summary, the combination of enabling layers and constraining rules shape the systemic openness of the systems design challenge by 'forcing' students to bring their designs together and evaluate the consequences–showing the dynamics of a growing system. The IoT Sandbox makes the systemic openness concrete and manipulable while still allowing the students to explore what would happen if their designed artifact is introduced in a different (functional) context.

3 EMBEDDING IN EDUCATION – A DESIGN CASE

When the students start with their IoT Sandbox based design project they are given a presentation that both sensitizes them to the systems design challenge as well as familiarizes them with the IoT
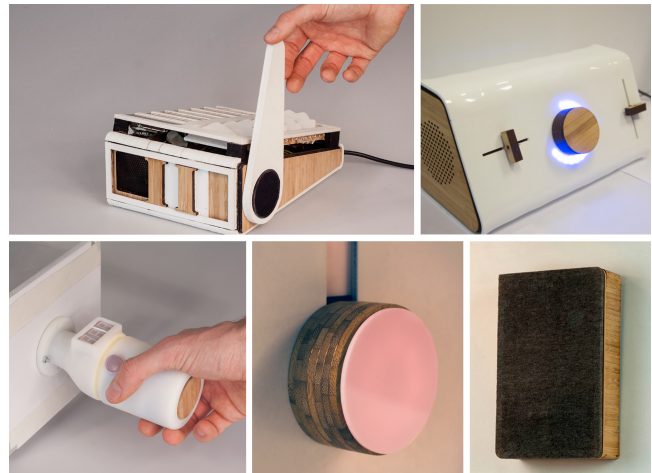
Sandbox. Former work is presented, and they are told that the previous mundane characters have decided to move and that a new family is moving in. They are given the names, ages and family relations between the mundane characters and given the task to elaborate a day in the life off those families. Using the IoT Sandbox as a three-dimensional pinboard students work through their combined scenarios of the day in the life the family, leaving traces by means of sticky notes in the process. This 2-hour workshop lays the foundation for the semester to come. After the sensitizing workshop the students start their designerly explorations while simultaneously furnishing the home and elaborating the mundane characters. In the following, we showcase a concrete group design project that developed from the basis of the sensitization and introduction to the IoT Sandbox.

In one of the first semesters that we used the IoT Sandbox, we assigned a group of master students the concrete challenge to design a family of systemic products for a house—inside the IoT Sandbox. The group chose to first work on a scenario where multiple connected products would be influenced by an overarching house 'system' that would support a set of three family values: sustainability, comfort and social cohesion (see Figure 2). Then, each member of the group set out to design a single connected product with a specific functionality target: lighting, heating, security, media and communication (see Figure 3).

Figure 3: Five connected artifacts featuring autonomous functionality and system functionality.

Figure 2: Simplified data flow diagram showing the systemic relations between connected home products based on family values.

The first artifact (top-left) is a (series of) media player(s). There is a media player in each room, and they share playlists, offer social listening (multiple people listening to the same songs) and they share presence data with the 'system'. The second artifact (top-right) is a communication mediator (unfinished) that streamlines casual communication (e.g., reminders, shopping lists, etc.) in the home. The third artifact (bottom-right) is a security system that

takes presence data from the other devices as well as from dedicated sensors. It communicates potential security breaches by tilting. The fourth artifact (bottom-middle) is a (series of) light controller(s). There is at least one light controller in each room, and they offer control over mood-lighting to support social cohesion. The light controllers use data from other artifacts to finetune the expressivity of the mood-lighting. The fifth and last artifact (bottom-left) is a (series of) smart thermostat(s). There is at least one in each room and it aims to balance energy control – it gives more rotational friction if much energy is used and it uses presence data from other artifacts to control the temperature in the rooms.

4 DISCUSSION

The IoT Sandbox and its mundane characters were perceived by many students as helpful. Yet there were also students who considered it to be an extra burden. The latter group only used the IoT Sandbox in the first weeks of the semester, mainly because we asked them to. In those latter cases the design challenge was consequently simplified to a 'simple' interaction design challenge and the systemic aspects were hardly touched. The successful projects, often group projects, offered design proposals with clear systemic qualities. It was noticeable that these benefited from being group projects (tasked with designing product families, like in the example above) with multiple designs that worked as a system within the confines of the group (at the same time these were master students so that could also explain their better understanding of the challenge). While initially scarce, in the later semesters, cross-project initiatives became more numerous. While there is certainly room for improvement, important steps have been taken as we received design proposals that have clear systemic qualities and that are arguably open for growth.

The students who worked on the design case that we presented above reflected on the utility of the IoT Sandbox in their process report. They bring forward that the close proximity to the IoT Sandbox helped "to form an accurate model of orientation", meaning that

it helped ground and calibrate their design proposals. They also critiqued the IoT Sandbox and stated that "to create a specific context to design for, seems paradoxical when you simultaneously create that context yourself". This feedback must be seen in the light of the early phase of the deployment of the IoT Sandbox in education – at that time we were still tuning the approach. Feedback such as that of this group of students, combined with our observations of the students' design processes led us to a new implementation of the mechanisms of cooperation and competition. The students in the design case were working with more than one group in a house but there was enough room for them to be comfortably out of each other's way. This can be read from their statements where they claim to have complete freedom of creating the environment in the IoT Sandbox. The important lesson there we learned there is that the IoT Sandbox needs to be 'crowded' with projects to make the mechanisms of cooperation and competition work. Pressure from other projects is needed so that there is a competition for (conceptual) space. Variation in projects is needed to create opportunity for meaningful cooperation.

Next to optimizing the implementation of the mechanisms of cooperation and competition we observed several additional points for improvement when working with the IoT Sandbox. A problem that became prominently visible during the first semesters of use is a consequence of the sandbox-like nature of the IoT Sandbox: it proved to be hard for the students to seek external validation for their design proposals 'in the wild'. In later semesters we coached our students to seek external validation, but it remains difficult to evaluate the systemic characteristics (i.e., the cross-project qualities) of the projects.

Another point for improvement concerns the use of data within but particularly between the design projects in the IoT Sandbox. In several of the projects (including the presented design case) the design proposals shared data as part of their functionality. The use of data as a material for design is one aspect of what makes these artifacts systemic artifacts. Yet, other aspects of systemic behavior such as co-dependence between artifacts, emergent functionality or even just simple forms of growth are harder to design for.

5 CONCLUSION

We have presented the IoT Sandbox as a tool and method for design in a systems context with explicit attention to its operation in design education. We have seen valuable work emerge from the hands of the students that worked with the IoT Sandbox and we feel that this has much to do with the mechanisms of cooperation and competition that the method builds on. The IoT Sandbox is instrumental in seeding, amplifying and enforcing mechanisms of cooperation and competition in systemic group design projects, and it is essential in making the design process systemic in itself. We will continue working with the platform and currently aim to better visualize the data that is shared in the physical model itself.

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