

# Setting the Stage for the Design of Highly Interactive Systems

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**Abstract:** This paper introduces the design of systems as a new challenge for the de field of design. The ‘one person – one product’ dictum is left in favour of complex systems consisting of many ‘nodes’. A recent design experience is taken as a starting point for a designerly reflection on systems design which, through a cycle of observations and reflections, leads to the identification of four design challenges: (1) designing into systems the ability to grow, (2) loci of interaction are needed, both for control but also to perceive what a system is capable of, (3) a new dynamic form language is required that accommodates action-centric interaction and (4) the energy use of such systems is difficult to control. The four challenges open up new design opportunities. The paper comes full circle as it discusses the quest of new design skills to meet these opportunities.

**Key words:** *Design, Highly Interactive Systems, Systems Design*

## 1. Introduction

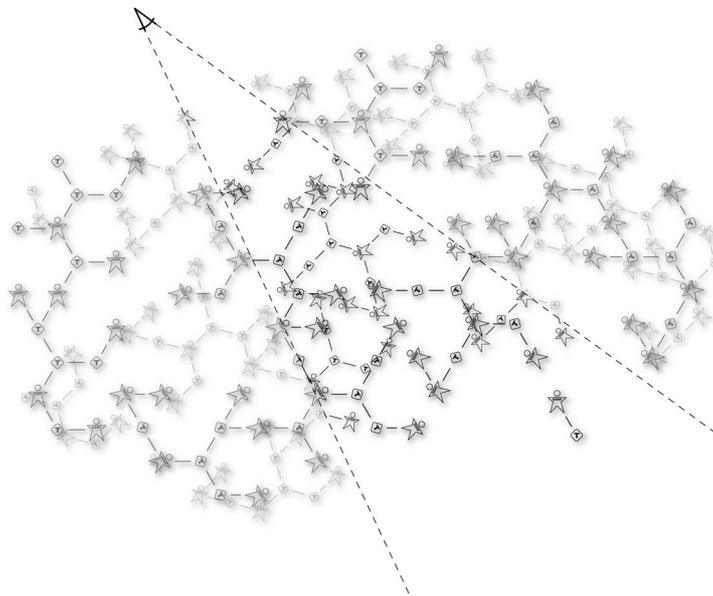
This paper introduces the design of systems as a new challenge for the field of design. While the design of systems has been the focus of research areas like ubiquitous computing [1], pervasive computing [2] or ambient intelligence [3] for the last decade, we observe that such systems have failed to make their wide-scale introduction into the home or the office. The state-of-the-art in such research is often distinctly technology driven. The research agenda is phrased in terms of key technologies and protocols (e.g., [4,5,6]) but seldomly in terms of user values or contextual opportunities. This results in a virtually endless stream of solutions without a problem: tables that can track the objects that are placed onto them, fridges that order fresh milk autonomously and mirrors that show the eight o’clock news. That is not to say that these systems have no potential. They promise an environment for the home and office that offers next generation functionality with natural interfaces and without the physical clutter of devices. They promise that people can be connected in new ways, to each other, but also to information systems and services. Still, even if the potential and promise of these systems to improve the quality of our lives has not materialized, it is as relevant now as it was before. Yet, we have to critically reflect on them to transform their potential into reality in a lived environment. To do this we leave the road of abstract technology push and start with a survey of the potential of systems design in the *lived reality*. We try not to identify new technologies or different contexts, instead we investigate how the systems could blossom when approached from a *design* perspective, that essentially includes the user and the broader physical and social context [7]. For this paper we use the home context as our focus. In what follows we first discuss how we understand systems, then we present our approach and dive into the subject matter by means of an example.

We use the example to identify four design challenges that will be instrumental in the future success of systems design. We end with a discussion of the new skills that are needed to design for systems.

## 2. Designing systems

We study how to design for systems. This topic is neither trivial nor well understood. The systems we envision increasingly become more complex, not in the least by the fact that these systems impact society in a profound way. We break the ‘one person – one product’ dictum in favour of a system of (interactive) products consisting of many ‘nodes’. It receives non-colocated inputs and produces outputs to multiple locations. Moreover, these inputs and outputs may be of different modality in the different interactive ‘nodes’. All this results in system behaviour that is less predictable, not only for the user, but, importantly, also for the designer. The complexity and unpredictability grows even further when we implement adaptive and self-learning behaviour in the ‘nodes’ or in links between them. Still, designing for systems involves more than ‘just’ designing the interactive ‘nodes’. The system behaviour is more than the sum of the behaviours of the nodes that define the system. This is similar to the behaviour of a flock of birds, that is more than the sum of the behaviours of the individual birds. The system behaves according to its own rules. The systems under investigation are woven into the social fabric of our lives and form, more then ever before, an integral part of it. This broadens the systems design challenge to not only include appearance, interaction, and technology issues but also to include social and cultural aspects. Societal relevance is not optional but a necessity for this new field of design.

## 3. Approach



**Figure 1:** The limited view of the designer on a given system

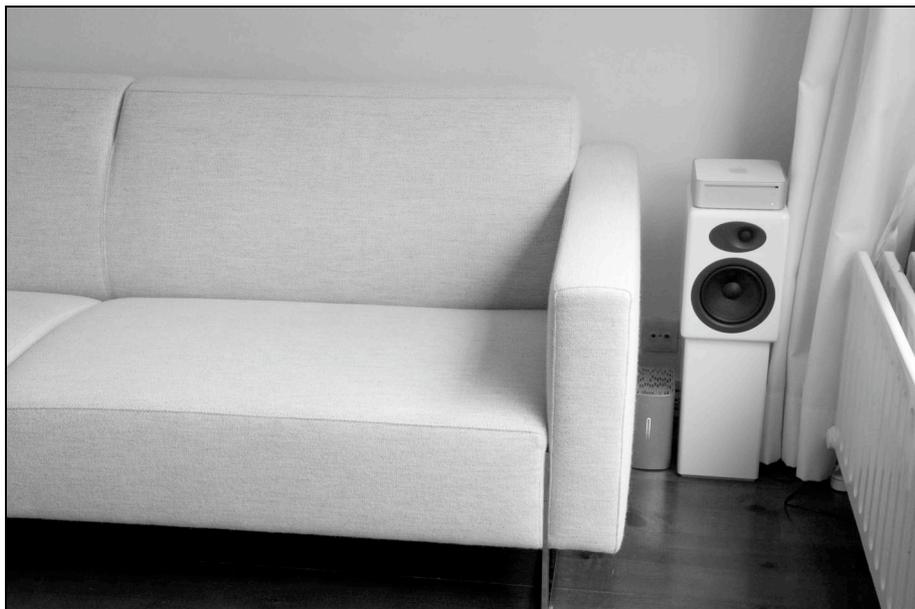
Our approach to systems design is guided by a design vision that highly regards relevance and experience [8]. That is, we believe that for the concept to truly flourish it has to mesh with the values of people and fit the context of use. It needs to be based in the reality of our lives and to be seamlessly woven into the social fabric of our lives. Yet, from a design perspective, there is very little experience with the design of systems and there are no methods ready at hand. This is caused by two reasons: (1) the field is immature from a design perspective and

(2) it is difficult, if not impossible, to have an overview of the complete system before it exists nor of its impact on society (see figure 1). Not only is the grasp of the designer of the system limited by his point of view, but systems also allow for many different, valid points of view due to their inherent complexity. We feel that this necessitates to start designing and take an *experiential* approach. We have to undergo the experience of living with these systems while we are designing them to make value judgements on the direction the solution should take.

#### 4. Directions for systems design

Here we present our vision on systems design that will guide us in the development of these systems in the *lived reality*. We use a recent design experience of the first author as a starting point for our reflection. We deliberately take a simple example to highlight the immense complexity that we *will* encounter in the future of systems design when systems go beyond analogs of products. In what follows we present our vision in the form of observations, reflection, challenges and design opportunities.

##### 4.1 A story to start with: building a media center



**Figure 2:** The simple media center

*Recently I decided to build a simple 'media center'. As I wanted to have a more elegant and customized solution than I could buy, I decided to design and build my own solution from scratch (see figure 2).*

*The system consists of a central computer that runs an audio server and a video server. Attached to this computer is a TV tuner and it can also playback DVDs through its internal DVD-player. Throughout the house several audio-streaming devices are present that pick up the wireless signal of the audio server and convert it to audible sound by means of amplified speakers. An old-fashioned CRT television acts as the video output of the system. An amalgam of hardware drivers, shareware and custom scripts ties these components together into a functional system. The system in its current incarnation is operated through both a dedicated remote control for audio and a wireless computer keyboard for TV and video*

## 4.2 Teaching the stupid house

*To build a media center in a real, lived environment is to experiment, explore, and fine-tune. It is not for the faint of heart as it involves buying expensive equipment that seems to never work right out of the box and that does not play nice with components of other suppliers. It is a process of teaching the stupid house to play by your rules.*

[observation] One of the leading goals in HCI research on systems is to create an adaptive and intelligent living environment (e.g., Ambient Intelligence [3]). The solutions offered are often technological utopias that are posed outside of the world as we know it. They do not allow for a gradual transition from the now to the future. They are in essence visions that demand a complete (and destructive) rebuilt of our lived environment.

[reflection] An important condition for systems design to blossom is to offer the ability for the system to gradually grow. That is, to have the system adapt to time. A potential user is not persuaded with the prospect of rebuilding his living environment, instead, we aim to seduce him with the possibility to slowly adapt his system to his wishes and needs, thereby creating a system that grows towards 'intelligence'. We need to find ways to make the houses that we own and appreciate more intelligent, not by rebuilding them, nor by equipping them with computers, sensors and actuators but by teaching them to behave.

[challenges] While designing into systems the ability to grow seems trivial it is fact not. We see several reasons for this. An obvious reason is that one arguably would like to include components from different manufacturers who might use different standards or protocols. This means that either manufacturers have to agree on standards or that intelligent system nodes have to be designed that can break through the barrier of incompatibility. Another challenge in the design of growing systems is that growth takes place over time. The growing system needs to be past and future proof. It goes without saying that these systems grow in a context of use and that designing how to setup and configure this is part of the design challenge of growing systems.

[design opportunity] The design opportunity then is to design systems that are able to grow. This offers not only possibilities for the gradual implementation of a system but it also shows much potential for customization.

## 4.3 Keeping up appearances

*To avoid the physical clutter of devices, the media centre that I built is hidden from sight (as far as possible). The traditional audio components are no more and instead there is just sound. In the future also the old CRT will be gone as there will be projected image. To control the media center I use remote controls (see figure 3), I cannot control the center directly as it is hidden.*



**Figure 3:** The remote controls to the system

[observation] One of the important research themes in HCI research on systems is the theme of interaction and control. As the physical components of the systems move away from sight, and with the components also the control surfaces, it is no longer possible to directly control the device itself, what is more, it is no longer even possible to perceive what the system is capable of (and what it cannot do) [9]. The holy grail is to find novel and natural ways of interaction with the systems. One of the strategies to do this is automation; on the basis of an analysis of user behaviour the system acts autonomously and adaptively. Another strategy that is often brought forward is speech and gesture recognition; the user talks to his system to operate it, as if it were a butler.

[reflection] In our view these strategies are problematic as they seem to present such systems not so much as an enabler, an amplifier of our (human) capabilities but as a subservient butler that grants us freedom of mundane tasks. They forget that man is not only served by alleviation but also by stimulation. Next to this we feel that the idea of speech recognition as it is implemented at this time has insurmountable problems. Speech does not encode into rational meaning but is meaning itself in all its richness (including not only structured sound but structured behaviour across many modalities) [10]. It emanates from the body and is understood in terms of the body. It is questionable if a rationalized and bodiless structure can capture this, let alone mimic this. In our vision the user of such systems is approached as if he was limited to a wheelchair and had to ask for everything needed over a sound-limited intercom system. This hardly seems to do right to the richness of our being. The question of control is relevant but it does not do to try to solve it through automation or speech interaction. Not only are those solutions far-off from the rich nature of people they also do not solve the problem of perceiving what a system can do [11].

[challenges] Designing meaningful action-possibilities has been the subject of many research projects (e.g., [8,12,13]) but these have always been operating in the ‘one person – one product’ dictum where there is a colocated relation between user and product. It is not a given that this knowledge applies unaltered in a systems design approach. Above we identify that an automation approach does not suffice and that loci of interaction are required, both for control but also to perceive what a system is capable of. Yet, it is not possible to design a control for a system as if it were an autonomous product; as if it were a physical but remote incarnation of the

system. Systems go beyond the closed (in terms of their functionality) reality of products, not only because they can grow (as outlined above) but also because they receive input from information sources and other users; they are woven into the technological and social fabric of our lives. This unpredictability necessitates new forms of information for use [12].

[design opportunity] The design opportunity then is to create meaningful yet ‘non-colocated’ loci of interaction that are unobtrusive while retaining the ability to perceive action-possibilities and control.

#### **4.4 The blessings and curses of emergent functionality**

*Where there are computers there are infinite possibilities, or so they say. In building my media center I only started to encounter the many possibilities that open when you disregard dedicated products in favour of open, generic systems. When combining a TV tuner with a hard disc it not only becomes possible to record TV shows, it also becomes possible to do time shifting or even to have the system record TV shows that fit your preferences automatically. Add an internet connection and with the right subscription your system becomes an on-demand video system. The possibilities are indeed endless.*

[observation] In HCI research the term ‘emergent functionality’ is often used. Originally from the field of artificial intelligence it describes the phenomenon of autonomous devices having new functionality when combined than that they have separately [14,15]. A well known example is that of a computer printer and a flatbed scanner that offer copier functionality when combined.

[reflection] The concept of emergent functionality offers a framework to capture the concept of functionality in a ‘growing’ system. The promise of ‘emergent functionality’ is that the utilization of existing devices or components is not only complemented but actually growing when adding new devices or components to a system. What is more, it promises a better use of resources, a screen can be used by your computer, by your TV, or by your videophone. Still, when we regard it from a design perspective, where we strive for meaningful interaction, it is a recipe for confusion. The functionality of a system grows in ways that are hard to predict and that makes it difficult, if not impossible, to predict how the interfaces of such systems will flesh out. In principle, these issues can be easily solved through expandable menu-structures. Current personal computer operating systems are a good example of how that could be implemented. Yet, there is much to say against such a solution. In doing so we arguably create a ‘weak generalist’ solution [16] that is very capable in accommodating the many emerging functionalities of a growing system but that offers information for use only in structure but not on an action level.

[challenges] The notion of growing systems seems to necessitate a ‘structural’ approach to interfacing the (emergent) functionality of the system. We concede the point that on a system level an abstract representation of the functionality of the system is needed, it is the modus operandi of software. Yet, while this might be so on a ‘system’ level we want to argue that it cannot be so on a level of use as the ways of people are action-centric. The loci of interaction that control the systems have to be as dynamic as the system they control. It is necessary to create a new dynamic form language that accommodates action-centric interaction.

[design opportunity] The design opportunity is then to design systems in such a way that the ‘generalist’ characteristics are retained on system level while on a level of use ‘specific’ characteristics prevail.

#### 4.5 Of energy vampires and the need to be online

*While laying out my media center I quickly ran out of wall-sockets; every add-on to the system came with its own external power supply (see figure 4). What was worse, as the system took shape it became clear that it was rather difficult to switch-off the system or parts of it after use. Not only are there always power supplies that leech power, the system is also distinctly sensitive to the order in which the parts are switched on or off. The manufacturers of the equipment that I used clearly intended it to be switched on all of the time.*



**Figure 4:** Wires and power-supplies

[observation] Energy use and system stability need to be regarded as related in growing systems. Stability has always been a key issue in systems design and is generally solved by keeping systems on standby. While, the notion of sustainable design and energy conservation is making its way into the field of HCI research [17,18], there can be found little reference to power and stability in literature when systems are approached from a growth perspective.

[reflection] Issues of energy use and system stability will inflict dedicated systems to a lesser extent than systems that are built ‘ad-hoc’. As we focus on the latter, we do need to question how to deal with the issue of power and stability as the invisibility of systems leads to invisibility of power drain and the need for stability often trumps the wish for energy conservation. When regarding sustainability and energy conservation, running the risk of over generalizing and stereotyping, there seem to be different approaches to this issue. On the one hand we see an ‘environmentalist’ approach that tries to make people more aware of their behaviour, on the other hand we observe a ‘pragmatic’ approach that strives to optimize energy performance in portable devices [6]. In the perspective of growing systems, we need both approaches as they strengthen each other. While we do believe that we have to make people aware of their energy use we think that that is simply not enough. If we do not provide the means to conserve energy other than reducing the (perceived) comfort of people we will hardly motivate them to do so. The efforts from the more ‘pragmatic’ approach to energy conservation will be instrumental in reaching the goal of using less energy while empowering people with the new possibilities that systems can offer.

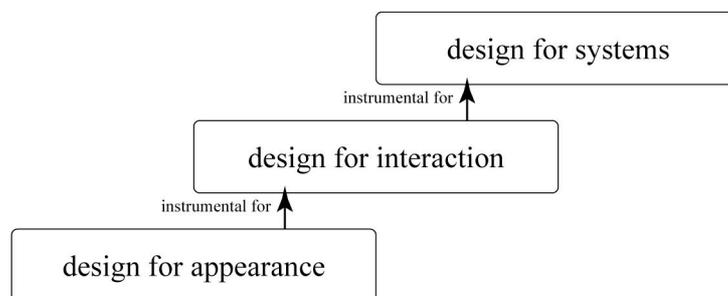
[challenges] The easiest solution in this context would take that shape of a ‘master power switch’ that simply takes a system off-line, thereby stopping its need for energy. Still, this would result in an undesired situation where systems can only offer their services when a user is present. Not only is this unwanted from an individual users’ perspective, it is incompatible with the nature of systems. This is best clarified with an example: if we look at one of the biggest systems we know, the internet, then it is inconceivable that for example ‘google’ is only available for our queries when its owners are in the office. Because, also on a smaller scale, systems will be woven into the social fabric of our lives, an energy control scheme based on location (i.e., a control switch triggered by our presence) cannot provide an appropriate solution. Still, we have also argued that the ‘always-on’ mentality is, in the end, not sustainable. Due to the complex and unpredictable nature of growing systems, the energy use of such systems is difficult to control.

[design opportunity] The design opportunity is then to design growing systems such that they respond to use in their energy footprint.

## 5. Methods and skills

In the previous paragraphs, we outlined the idea of growing systems and highlighted several design opportunities resulting from that idea. What strikes us as remarkable is that even when discussing a very simple system (that even has equivalents in the ‘one person – one product’ dictum) the complexity of the design opportunities and challenges is very high. In our view, this strengthens our argument from the start of this paper that in order to get a grip on *how to design for systems* an experiential approach is essential. We have no definitive answer to the methodology question. But we feel confident that through our hands-on approach our insight in these matters grows until we can compile it into a relevant methodology. In other words, the uncertainty of method and the complex nature of systems will necessitate a research-through-design [12] approach with ‘doing’ as the mechanism for obtaining insight into the process at hand guided by relevant theory and a vision of what to achieve. The question that is left is the question of what kinds of skills are needed to design for systems.

Through time design has been characterized by different foci. Design started with a strong emphasis on appearance, it evolved towards an emphasis on interaction and now it is setting up to focus on the design of systems. As a result of the changing practice the skills involved in designing systems are different from the skills that were required before, (see figure 5). Below we discuss the skills that are necessary for the different foci of design.



**Figure 5:** the skills needed for designing systems of (interactive) products.

Design for appearance: ‘Classic’ design has a strong focus on appearance. The skills that are required in the profession reflect this characteristic. They are focused on optimizing the quality of appearance and they operate in the same medium as the design challenge (i.e., the physical).

Design for interaction: When we shift toward the design of interactive products the nature of the design challenge changes: the reciprocity of action and reaction gains characteristics beyond the physical into the realm of the virtual. The design challenge concerns not only the form but also the behaviour of the product. Yet our skills necessarily operate in the physical. The skills that are necessary to optimize the quality of appearance become instrumental for optimizing the quality of interaction; to meaningfully express the possibility to act in form, requires mastering the skill to shape form. Yet, designing for interaction also requires new skills. These have to do with the design of the temporal characteristics of interaction and range from the design of behaviour to the design of experiential interactive prototypes.

Design for systems: The nature of the design challenge changes again when designing for systems: the interactive products that had the single focus in the earlier situation now are ‘only’ the parts of a bigger system that is more than ever interwoven in the social fabric of our lives. As a result, the skills required for the design of systems will be different from the skills required for the design of interactive products where, in their turn, the interaction design skills will be instrumental.

There will be overlap between the skills needed for ‘design for interaction’ and ‘design for appearance’ but there will also be a need for new skills. Previously we argued for an experiential approach with ‘doing’ as the mechanism for obtaining insight into the design process. The needed skills are partial to this approach; they will be geared towards prototyping and testing. On the other hand, our application domain (i.e., the design of systems of interactive products) also influences the skills that will be required. The technology behind these systems (e.g., communication protocols, learning algorithms, etc.) has to be well understood and it is crucial that we incorporate these into our repertoire of skills. It is obvious that it will be hardly feasible to find all of these skills in one person but we also think that this is unwanted. The multiplicity of viewpoints that different backgrounds afford on a given (system) design challenge will enrich and widen its solution domain. Therefore, we aim for a multi-disciplinary approach that has (or develops), on a team level, the full repertoire of skills that are essential in our systems context. We strive for an integral design of systems through the integration of the different disciplines that can be found within the discipline of Design and the disciplines that are subsidiary.

## 6. Concluding

When we regard the systems themselves, we feel that it is not the question *if* these systems will physicalize (virtualize) but *how* these systems come into being. We are convinced that the discipline of product design is to lead here. We observe that in systems design many technological specialities come together, each with their own goals and aims. Yet, despite all technological advancements, the value of the systems will not be found in technology as such but in how we *use* this technology. Shaping and integrating this is the domain of design.

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